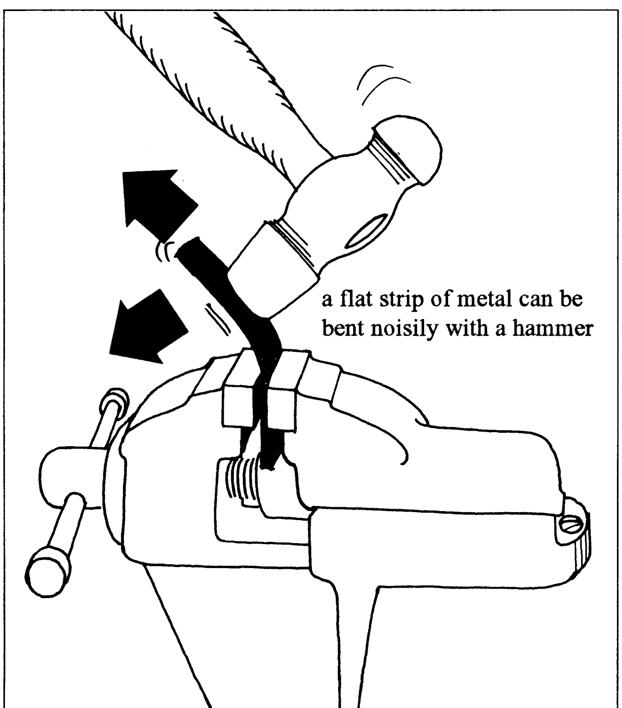
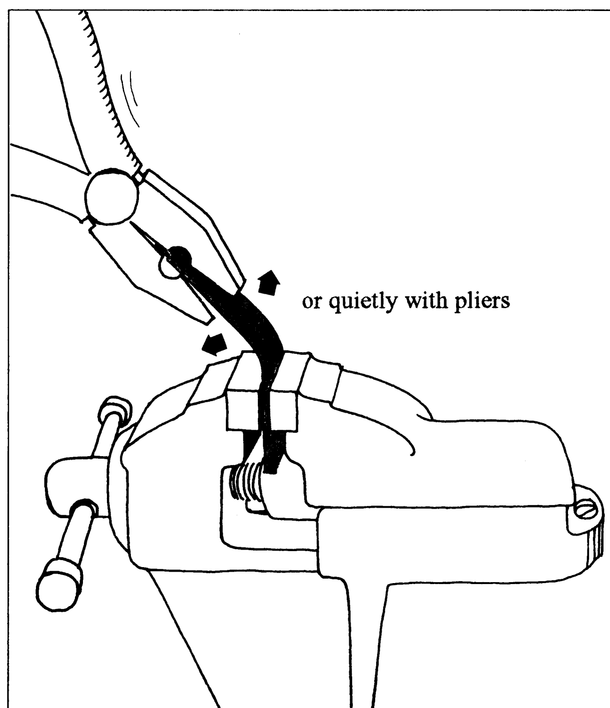
CHANGES IN FORCE, PRESSURE, OR SPEED PRODUCE NOISE

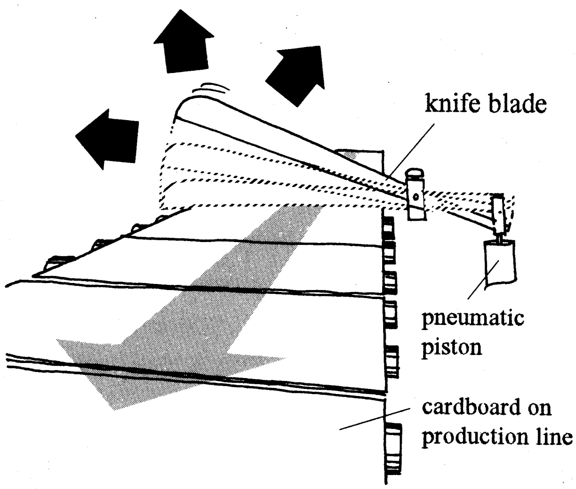
Sound is always produced by changes in force, pressure or speed. Large changes produce loud noises, small changes produce less noise. In many processes, the same result can be achieved with the application of high power for a short period of time or with less power over a longer period. The former results in high noise levels, while the latter produces much less noise.

Principle





Application with stamping and cutting equipment

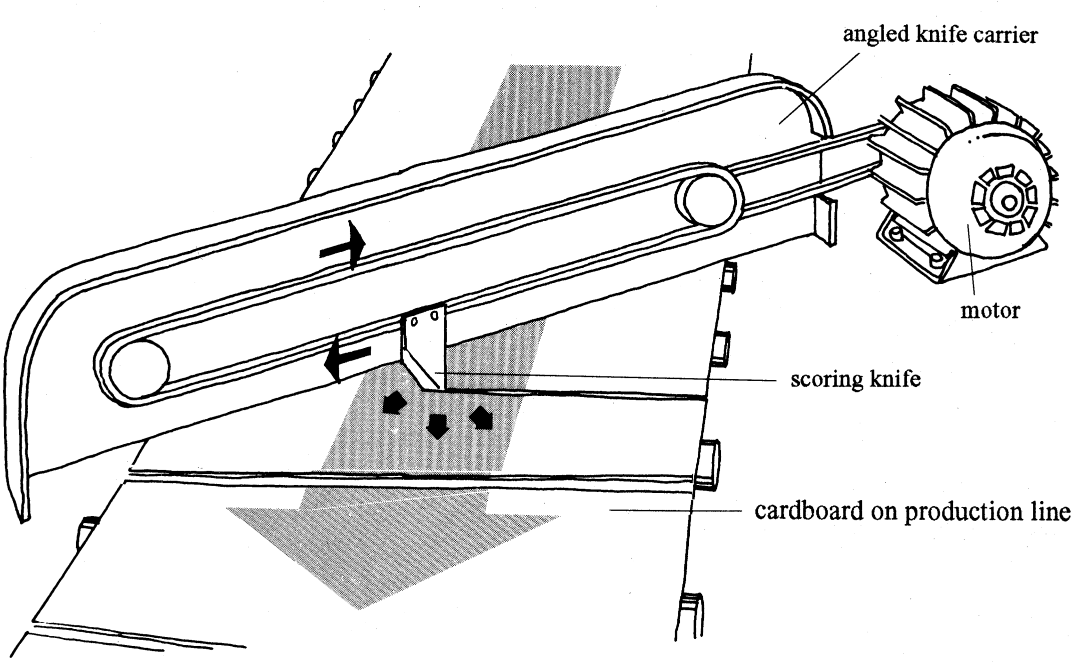


EXAMPLE

In a box-making machine, cardboard is cut with a guillotine. The knife must strike very rapidly and with great force in order for the cut to be perpendicular to the direction of motion. Much noise results.

CONTROL MEASURE

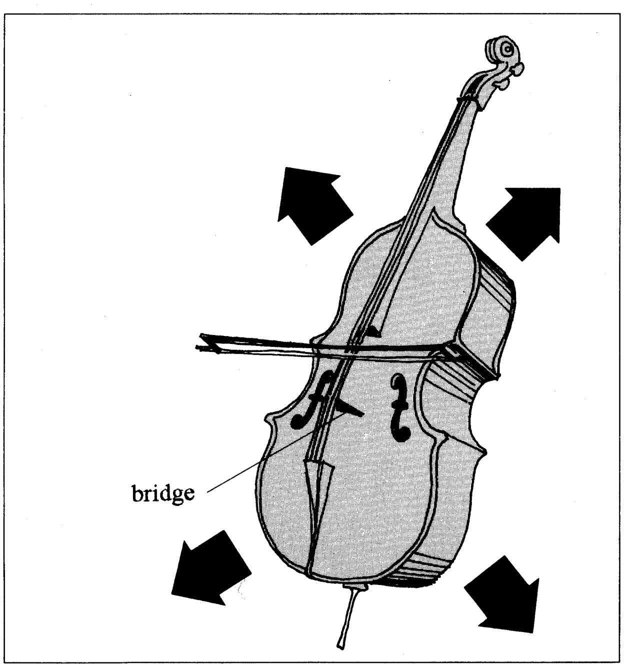
Using a knife blade which travels across the production line, the cardboard can be scored with minimal force over a longer period of time. Since the cardboard strip is in continuous motion, the knife must travel at an angle with the moving production line in order for the cut to be perpendicular. The cutting is practically noise-free.

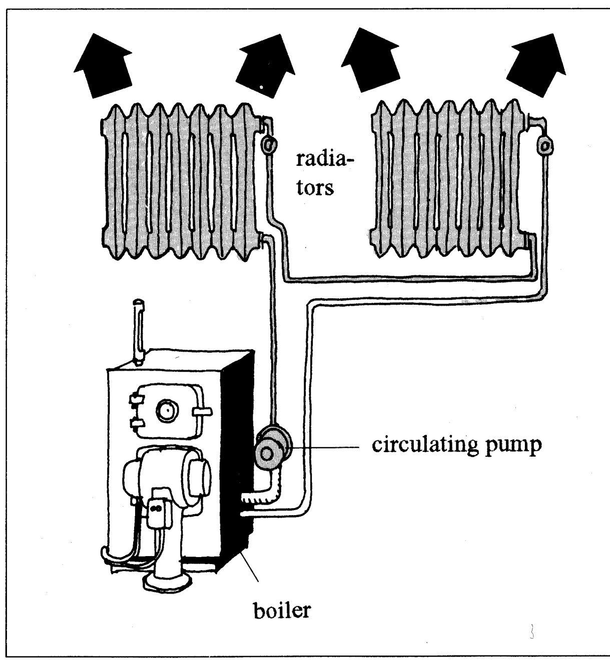


AIRBORNE SOUND IS USUALLY PRODUCED BY VIBRATION IN SOLIDS AND FLUIDS

When we use the word sound in everyday speech, we usually mean airborne sound. Airborne sound is normally produced by vibrations in solid materials - structureborne sound - or pressure variations in fluids - fluidborne sound - which are coupled to a surface that radiates airborne sound. For example, vibrations of the strings of a stringed instrument are transmitted through the bridge to the sound box. When the sound box vibrates, sound is transmitted to the surrounding air. A circulating pump produces pressure variations in the water of a heating system. The fluidborne vibrations are transmitted to the radiators whose large surface areas radiate airborne sound.

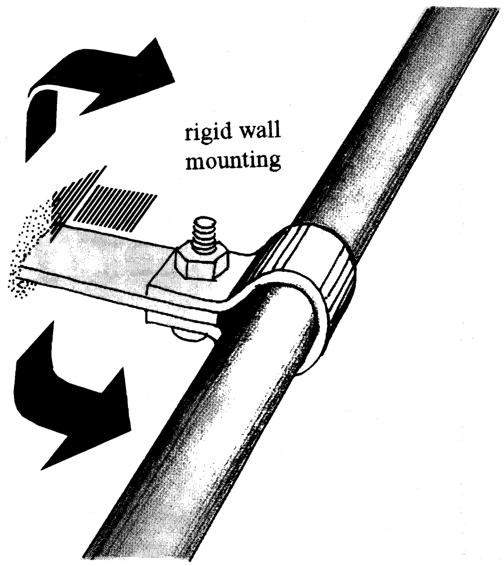
Principle





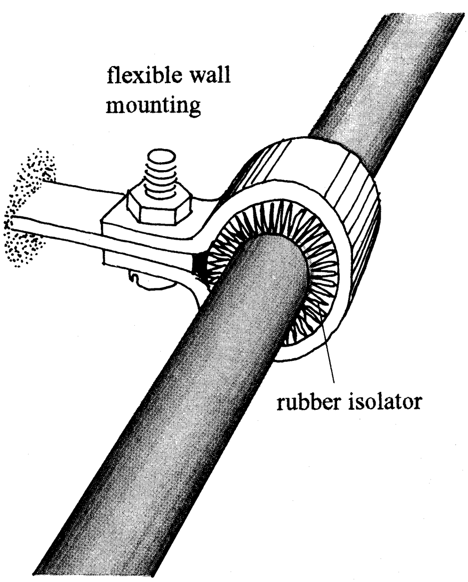
EXAMPLE

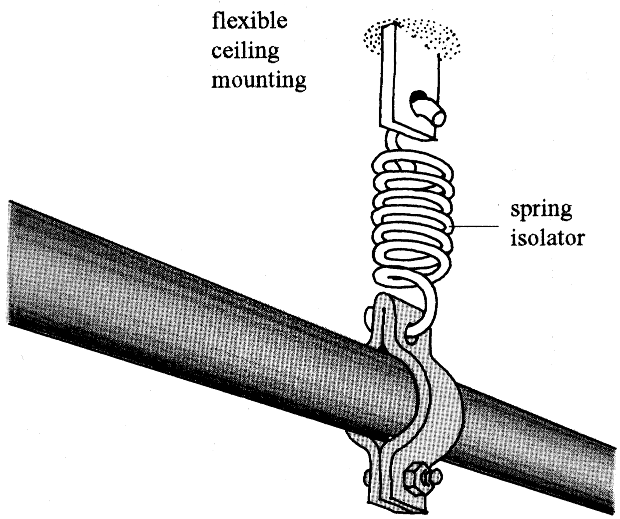
The radiation of sound from a pipe with a small diameter is usually negligible. However, a rigid connection of the pipe to an efficient radiator like a wall or a ceiling may convert the pipe into a noise problem.



CONTROL MEASURE

If flexible supports are substituted for rigid connections, the pipe vibrations will not be transmitted. This type of isolation is usually necessary for refrigeration and hydraulic lines.



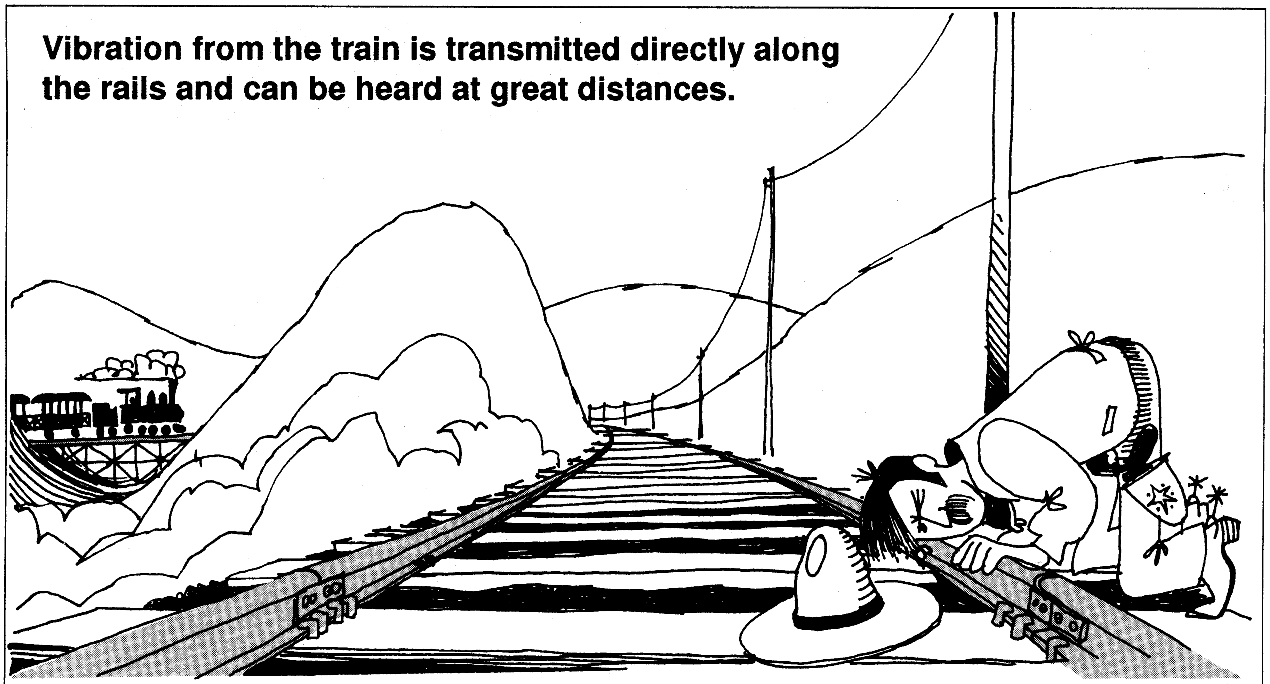


STRUCTUREBORNE SOUND TRAVELS GREAT DISTANCES

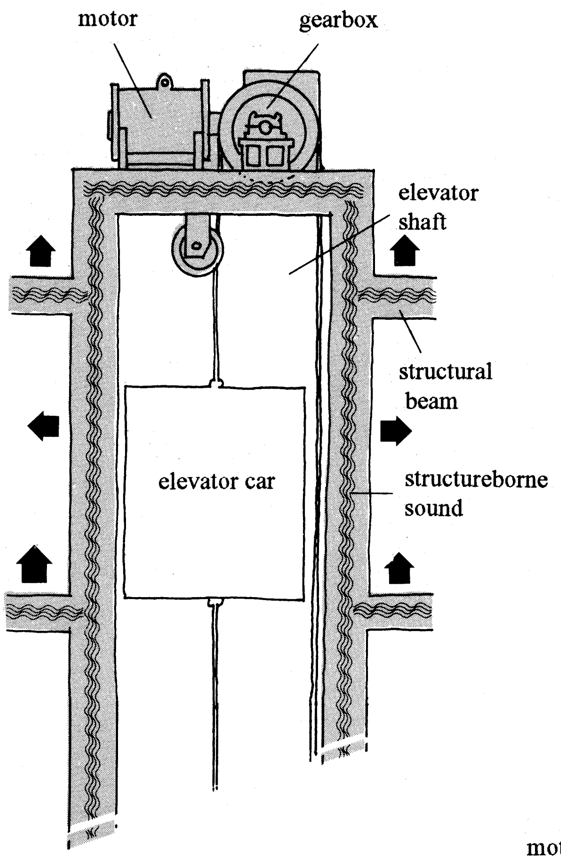
Vibrations in solids can travel great distances before producing airborne sound. This problem is especially pronounced in concrete buildings and on ships. When the structureborne sound reaches a large surface, the airborne sound radiated can become a problem. The best solution is to block the vibrations as close to the source as possible.

Principle

Vibration from the train is transmitted directly along the rails and can be heard at great distances.



Application in the framework of buildings and machines

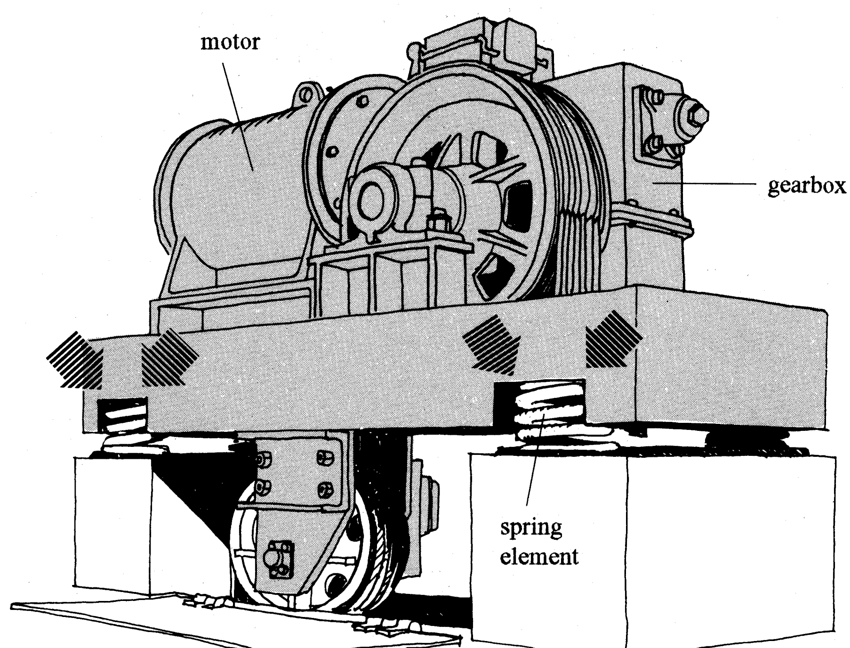


CONTROL MEASURE

The elevator drive can be isolated from the building structure by flexible elements. Further reduction can be achieved by constructing the elevator shaft and installing the drive so that they are completely isolated from the rest of the building structure.

EXAMPLE

Vibrations and stop/start shocks from an elevator drive are transmitted throughout a building. Structureborne sound is carried hundreds of meters in the concrete skeleton, virtually without attenuation.

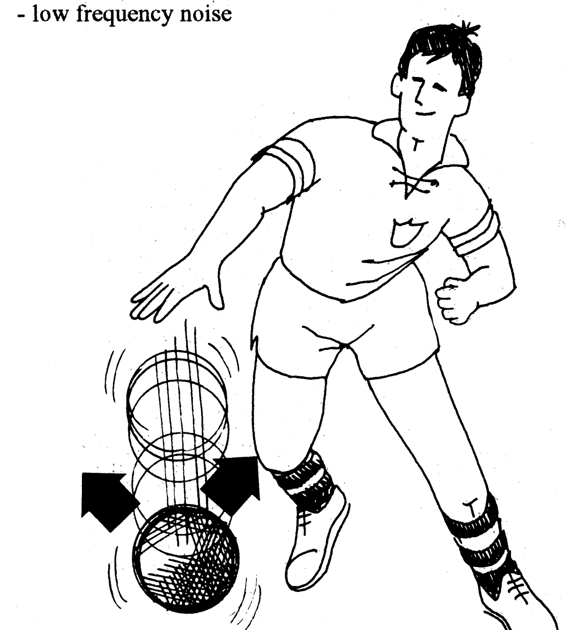


THE RATE OF CHANGE DETERMINES THE AMOUNT OF HIGH FREQUENCY NOISE

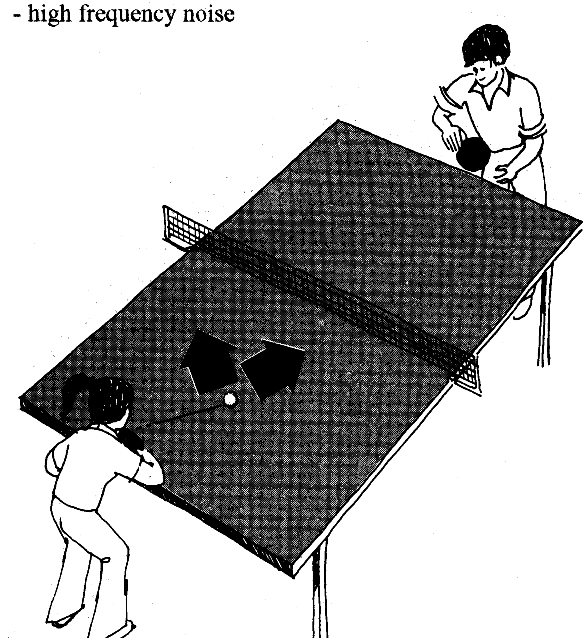
The more rapid the change in force, pressure or speed, the more dominant is the high frequency noise. A very rapid change produces a shorter pulse which has higher dominant frequencies. The rate of change is often determined by the resilience of the two impacting surfaces - the more they deform, the longer they are in contact and the lower the dominant frequencies. When bouncing a basketball on the floor, the ball is in contact with the floor for a relatively long time and the dominant frequency is low. The ping pong ball is in contact with the table for a very short time, and the dominant frequencies are much higher.

Principle

long-lasting impact against floor
- low frequency noise



short impact against table
- high frequency noise

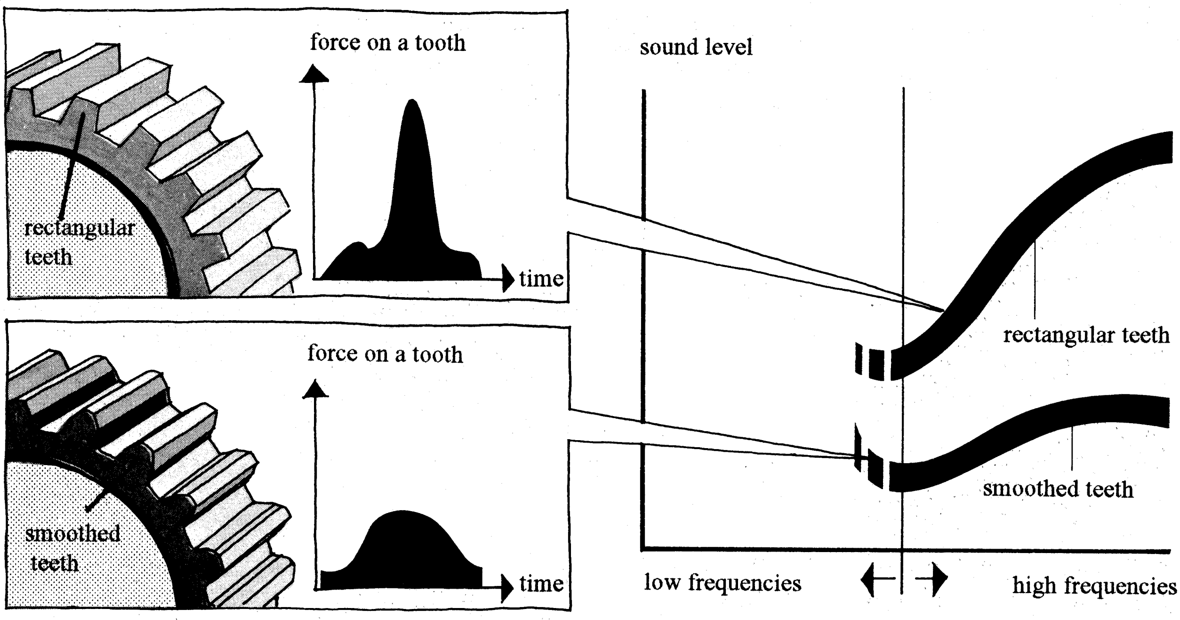


EXAMPLE

With a rough gear design (rectangular teeth), the force on the teeth rises and falls rapidly. Much high frequency noise is generated.

CONTROL MEASURE

With a smooth gear design (rounded teeth), the teeth fit more smoothly together, the force transfer is more continuous and the high frequency noise is reduced. Because the maximum force is reduced when the teeth engage, the sound level is lower at all frequencies than it is with the rectangular tooth design.

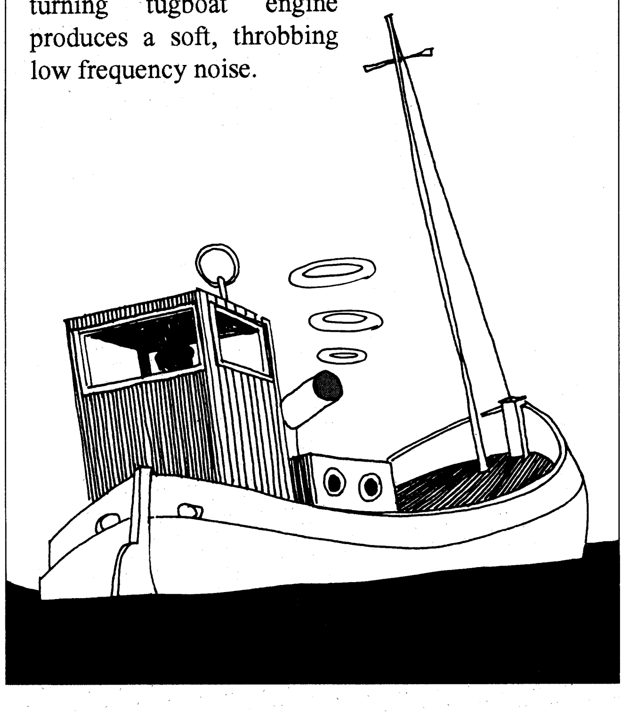


THE SLOWER THE REPETITIONS, THE LOWER THE FREQUENCIES OF THE NOISE

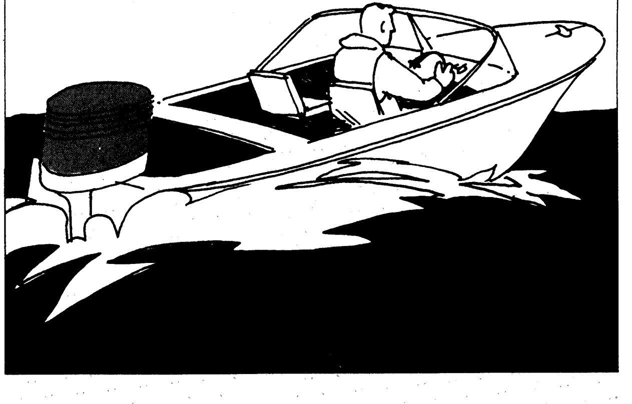
The amount of low frequency noise produced by a sound source depends primarily on the rate at which changes in force, pressure, and speed are repeated. The longer the interval between repetitions, the lower the frequencies of the noise generated. The level of the noise depends upon the magnitude of the changes.

Principle

The exhaust from a slowly turning tugboat engine produces a soft, throbbing low frequency noise.

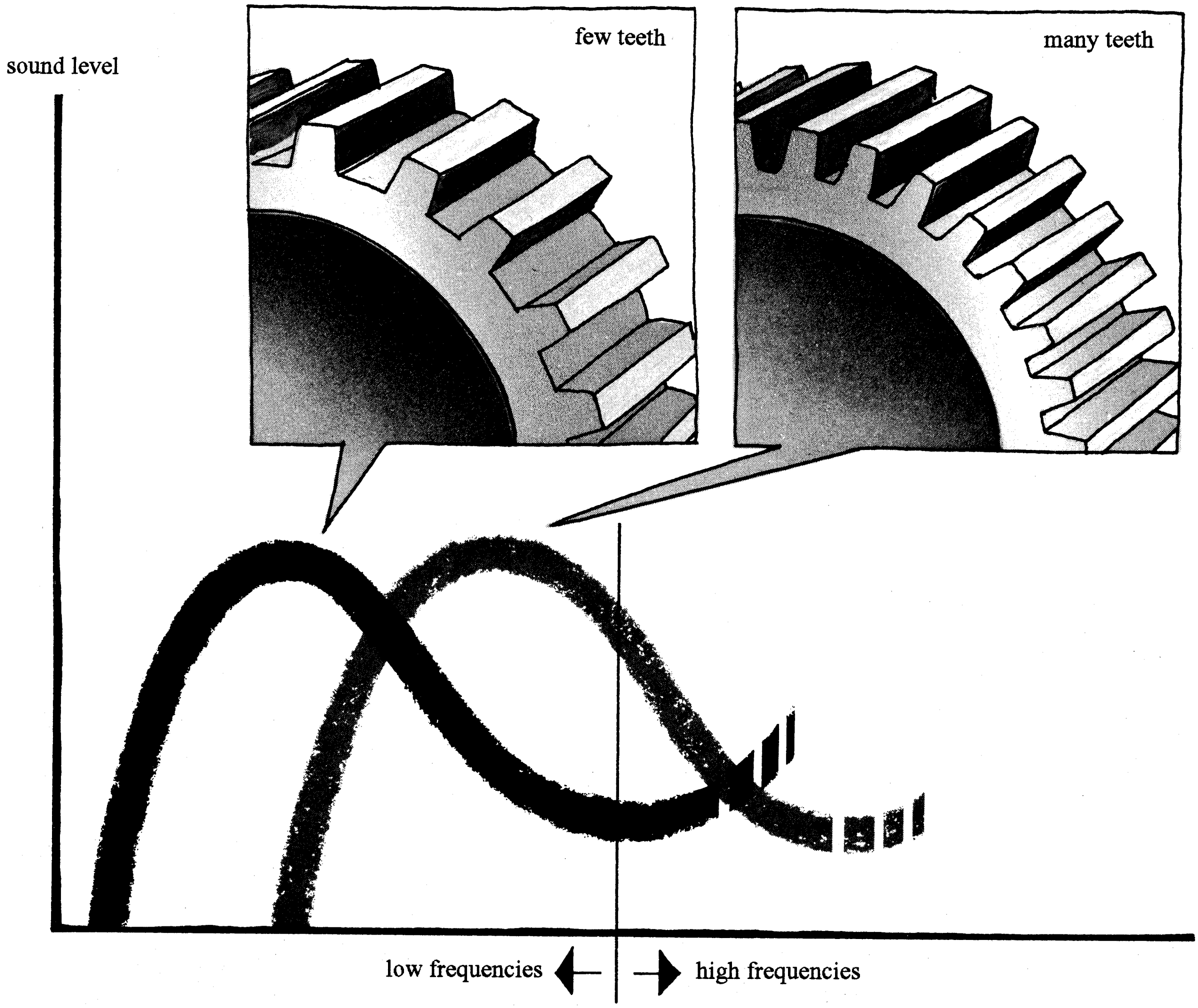


An outboard motor's rapidly repeated firing produces higher frequency noise.



EXAMPLE

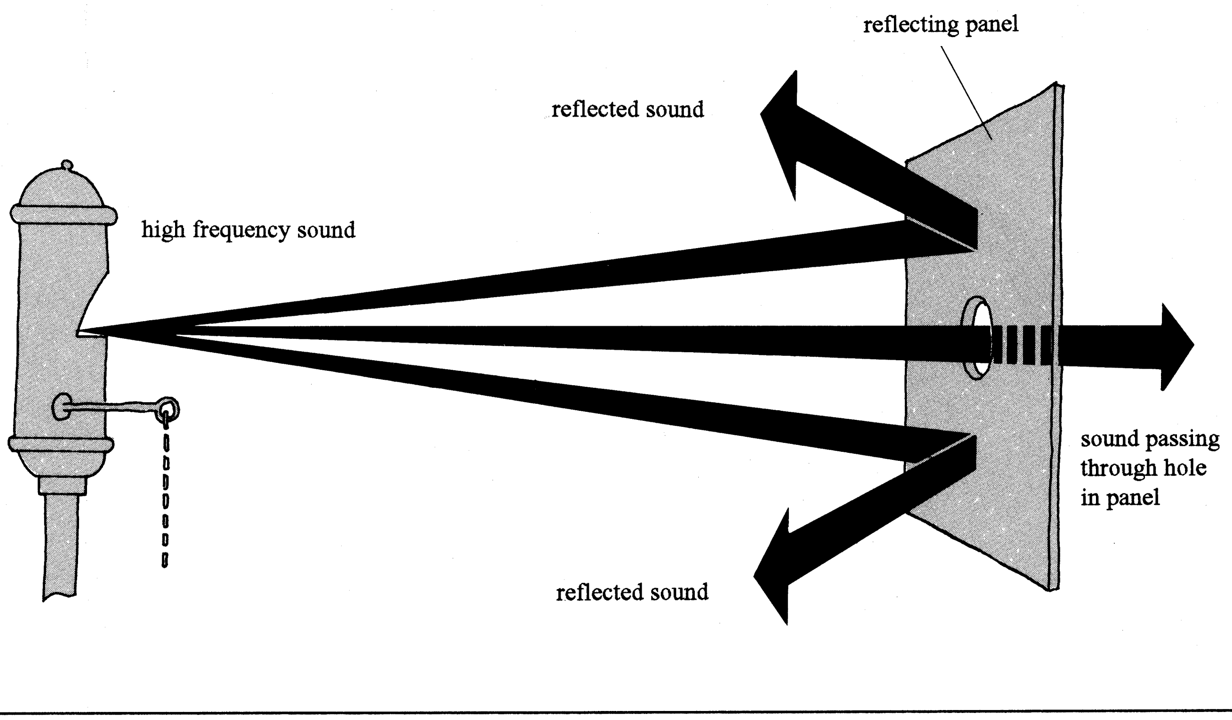
Two gear wheels are the same size, but they have different numbers of teeth. The principal source of noise in a gearbox is the contact of one tooth with the corresponding tooth on the gear wheel in mesh with it. If the gear wheels rotate at the same speed, the gear with fewer teeth will produce a lower frequency noise.



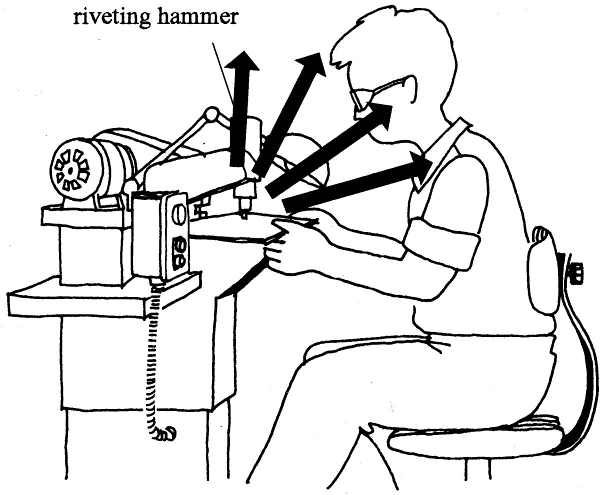
HIGH FREQUENCY SOUND IS HIGHLY DIRECTIONAL AND EASY TO REFLECT

When high frequency sound strikes a hard surface, it is reflected just as light is reflected from a mirror, but passes directly through any holes in the surface without change of direction. High frequency sound does not bend around corners.

Principle



Application of screening high frequency noise

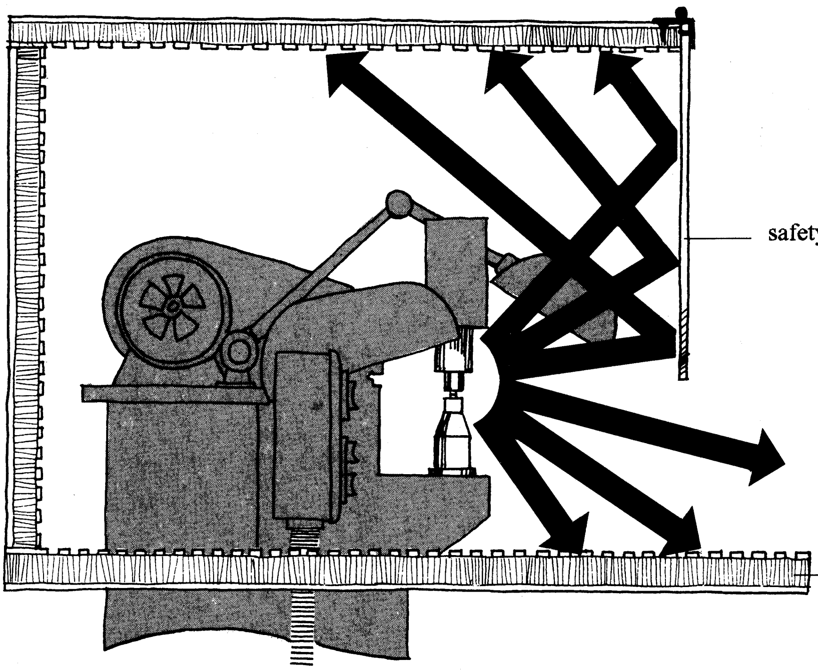


EXAMPLE

High frequency noise travels directly from the high-speed riveting machine to the worker' s ears.

CONTROL MEASURE

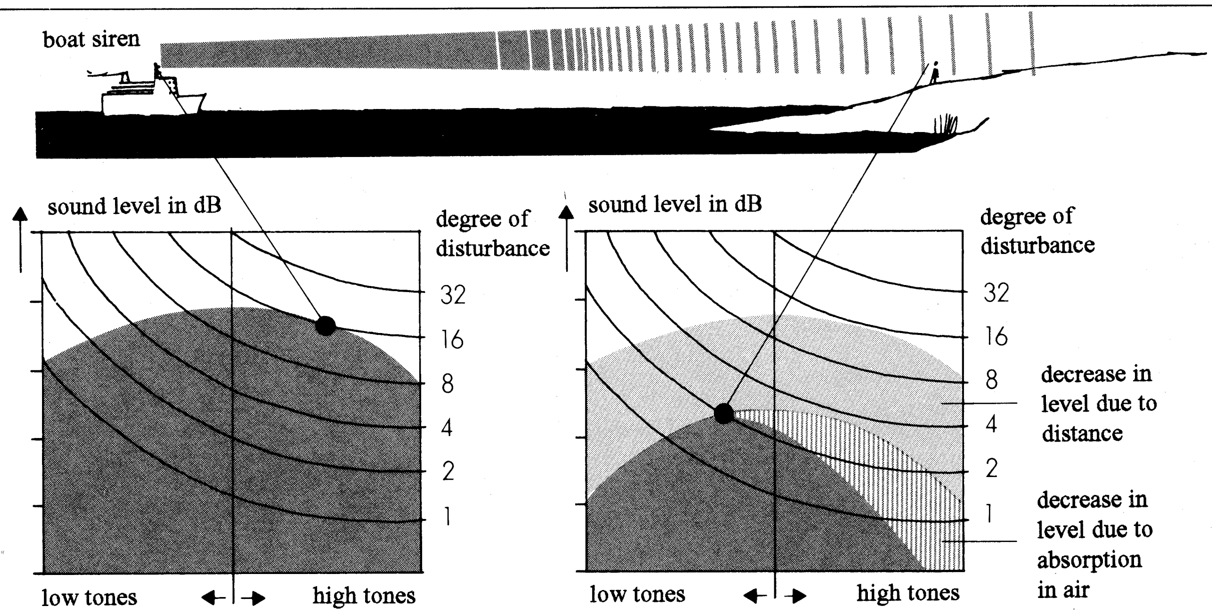
A sound-isolating enclosure, open at the bottom of the side facing the operator, is installed around the machine. The inside surfaces of the enclosure are lined with sound-absorptive material, for example, foam plastic. The upper portion of the side facing the operator is fitted with safety glass. The glass reflects the sound directed at the ears of the operator to the sound-absorptive lining. The sound level at the ears of the operator is reduced accordingly.



HIGH FREQUENCY SOUND IS GREATLY REDUCED BY PASSING THROUGH AIR

High frequency sound is reduced more effectively than low frequency sound by passing through air. In addition, it is easier to insulate and shield. If the noise source does not cause problems in its immediate vicinity, it may therefore be worthwhile to shift the sound toward higher frequencies

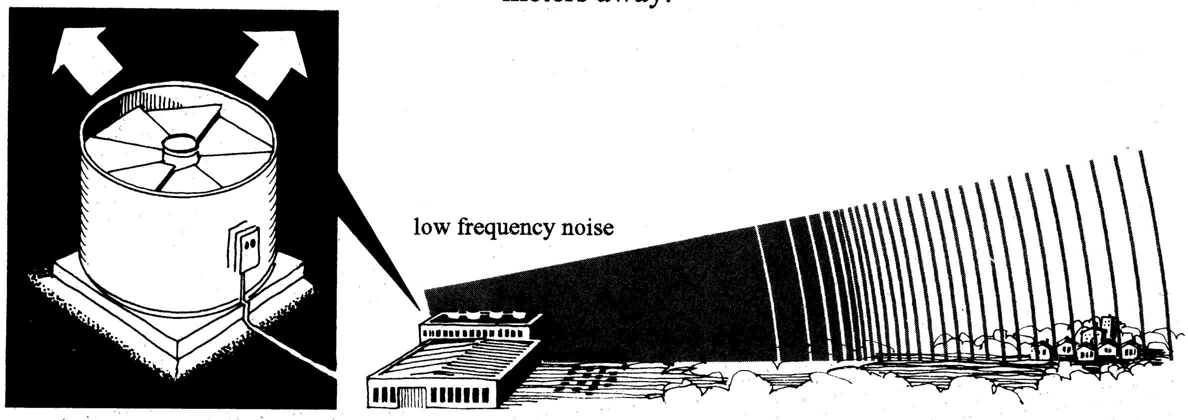
Principle



The boat siren, which seems extremely loud to those on board, is much less loud at a distance

EXAMPLE

The low frequency noise from roof fans in an industrial building disturbs residents of houses 400 meters away.

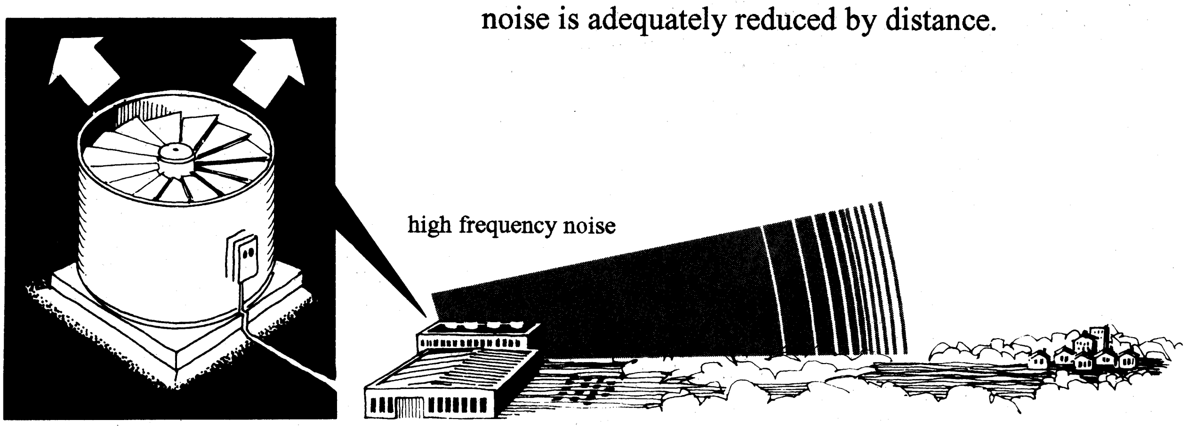


roof fan with few blades

residential community

CONTROL MEASURE

The rooftop fan is replaced by another of similar capacity but with a larger number of fan blades. This produces less low frequency noise and more high frequency noise. The low frequency noise no longer causes disturbances, and the high-frequency noise is adequately reduced by distance.



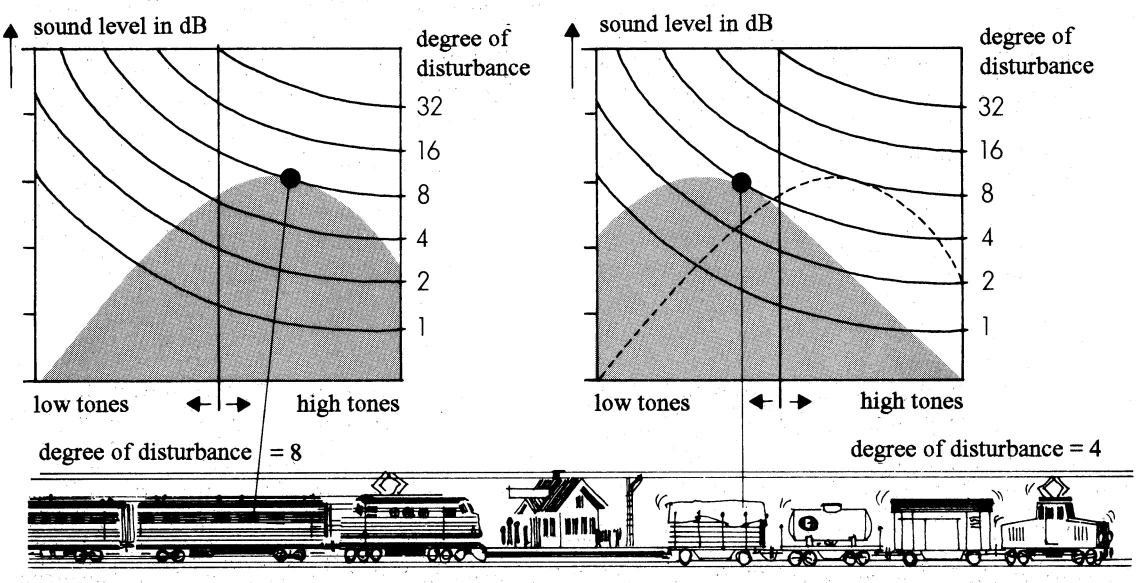
roof fan with many blades

residential community

LOW FREQUENCY NOISE IS LESS DISTURBING

The human ear is less sensitive to low frequency noise than to high frequency noise. If it is not possible to reduce the noise, it may be possible to change it so that more of it is at lower frequencies.

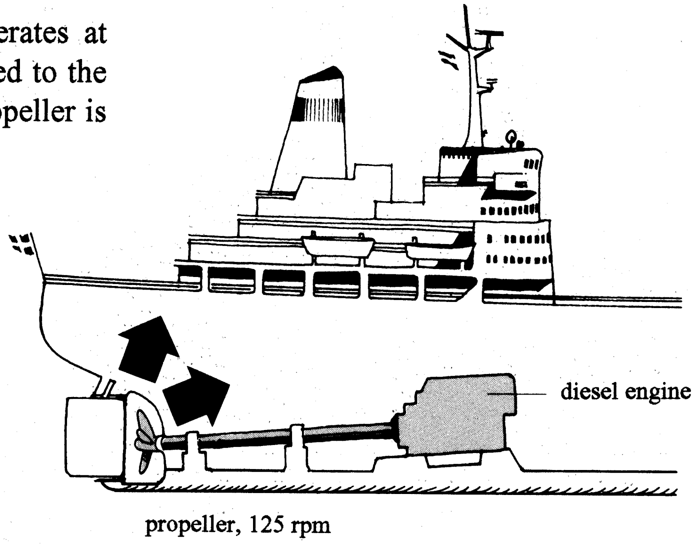
Principle



Two passing trains make equal amounts of noise, but one is more disturbing because it moves faster, causing more rapid impacts and creating higher frequency noise

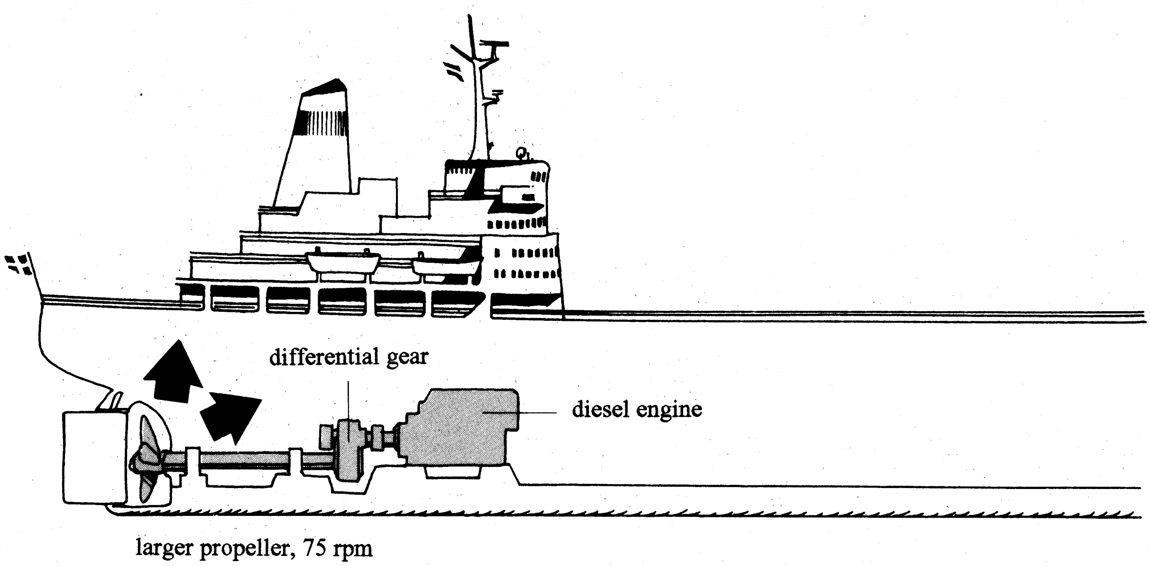
EXAMPLE

The diesel engine in a ship operates at 125 rpm, and is directly connected to the propeller. The noise from the propeller is extremely disturbing on board.



CONTROL MEASURE

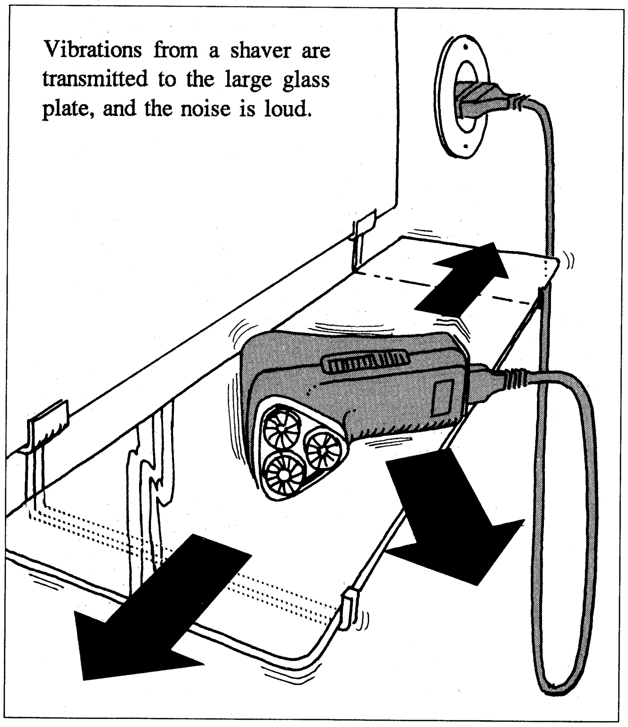
A differential gear is installed between the motor and the propeller so that the propeller can revolve at 75 rpm. The propeller is replaced by a larger one. The noise is shifted to a lower frequency, making it less disturbing.



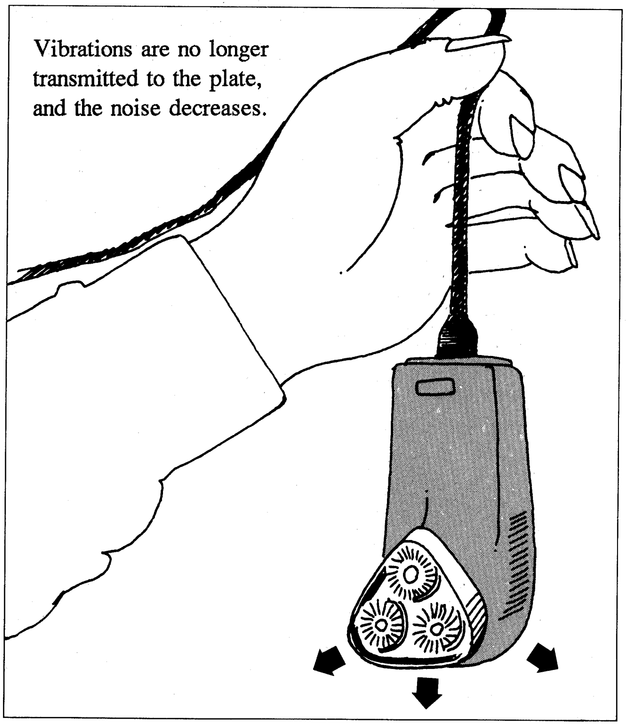
MAKE VIBRATING SURFACES AS SMALL AS POSSIBLE

An object with a small surface area may vibrate intensely without a great deal of noise being radiated. The higher the frequencies, the smaller the surface must be to prevent disturbance. Since machines will always vibrate to some extent, noise control will be aided if the machinery parts and covers are kept as small as possible.

Principle

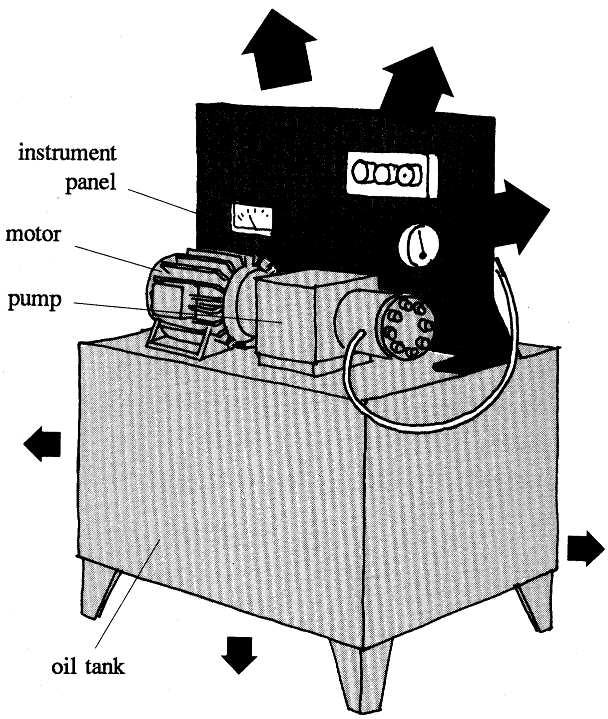


Vibrations from a shaver are transmitted to the large glass plate, and the noise is loud.



Vibrations are no longer transmitted to the plate, and the noise decreases.

Application with reduced radiating surface

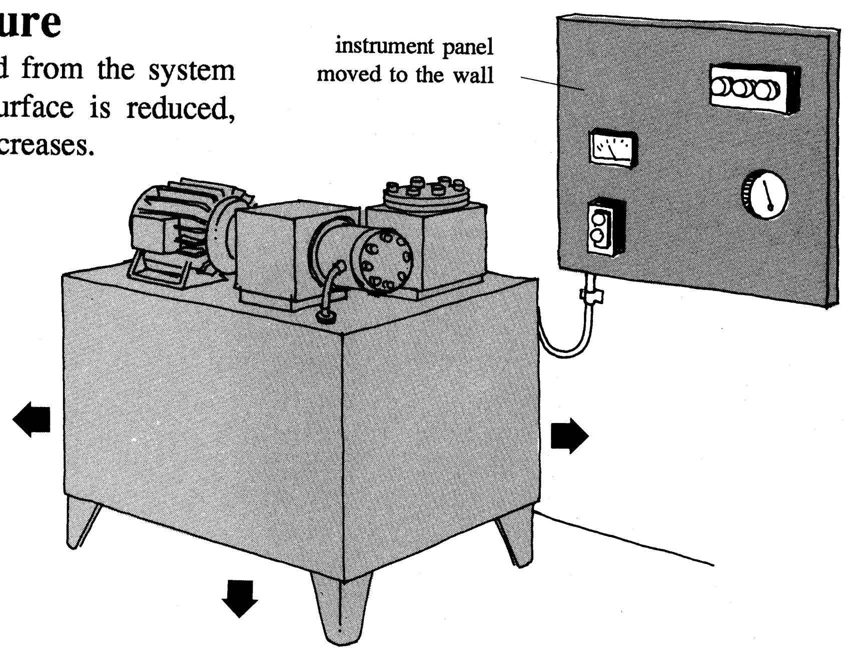


Example

Most of the noise of the hydraulic system noise comes from the instrument panel.

Control Measure

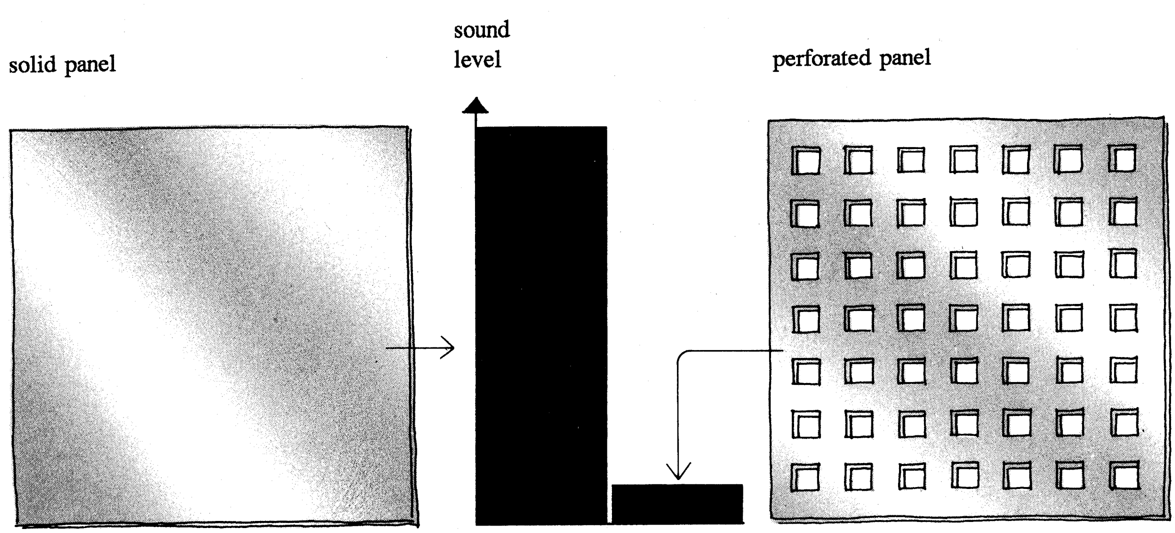
The panel is detatched from the system itself, the vibrating surface is reduced, and the noise level decreases.



DENSELY PERFORATED PLATES PRODUCE LESS NOISE

Large vibrating surfaces cannot always be avoided. The vibrating surface pumps air back and forth like the piston of a pump, causing sound radiation. If the panel is perforated, the "piston" leaks, and the pump functions poorly. Alternatives to perforated plates include mesh, gratings, and expanded metal.

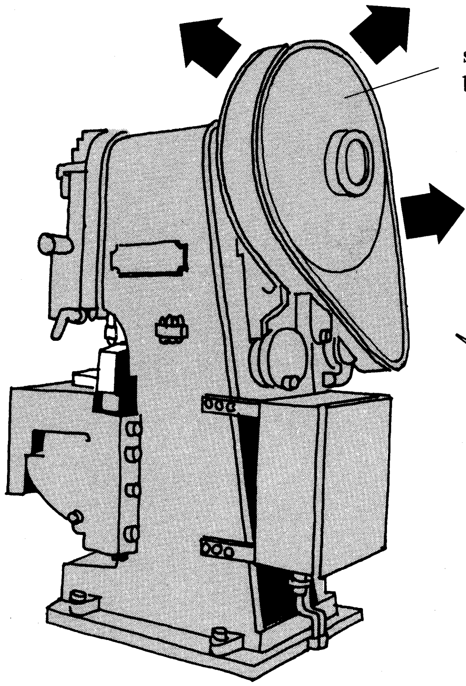
Principle

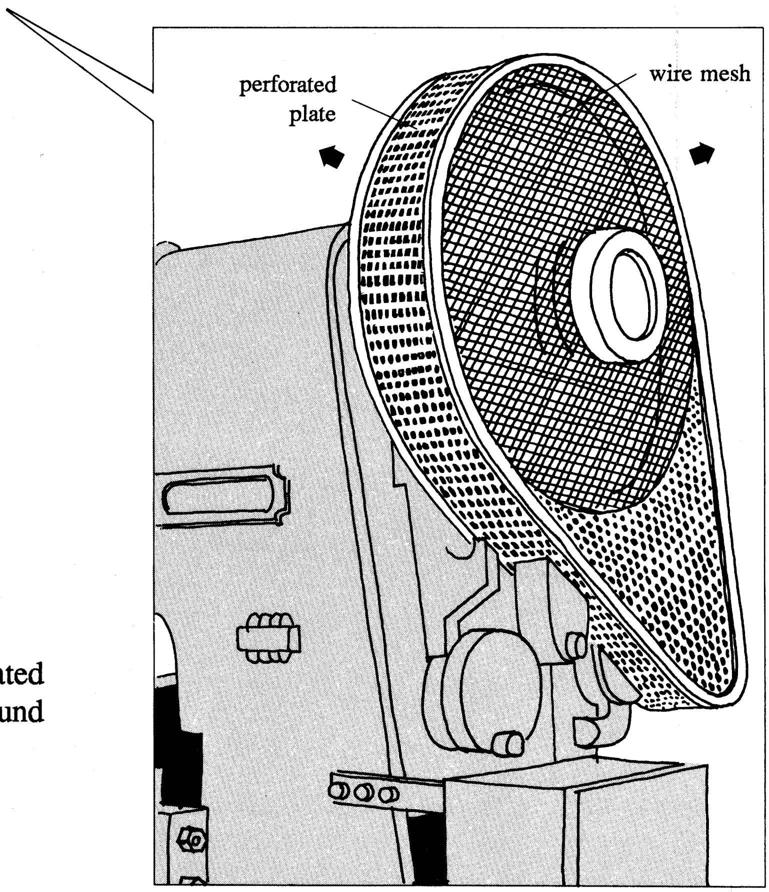


Application of hoods and protective covers

Example

The protective cover over the fly–wheel and belt drive of a press is a major noise source. The cover is made of solid sheet metal.





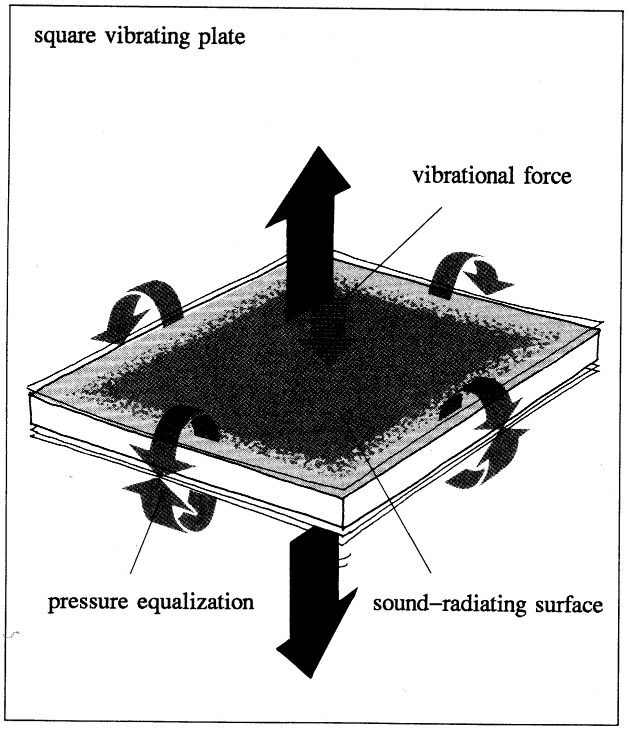
Control Measure

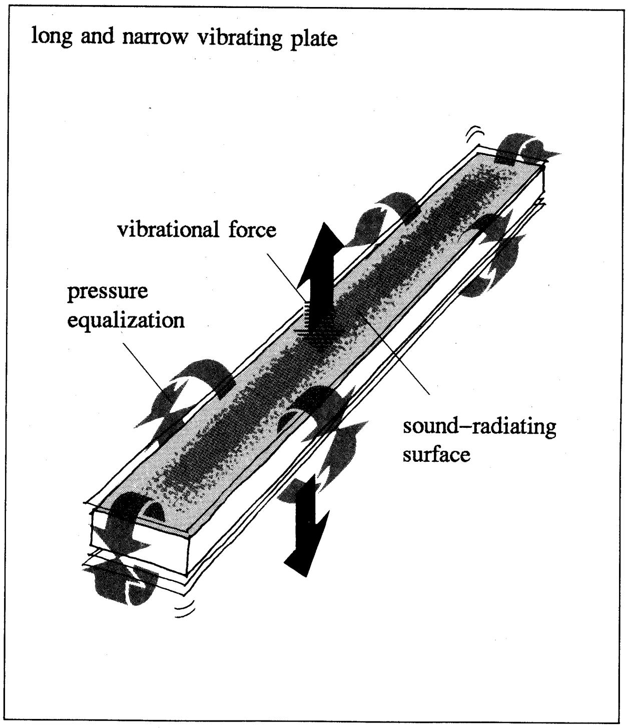
A new cover is made of perforated sheet metal and wire mesh. Sound radiation is reduced.

A LONG, NARROW PLATE PRODUCES LESS SOUND THAN A SQUARE ONE

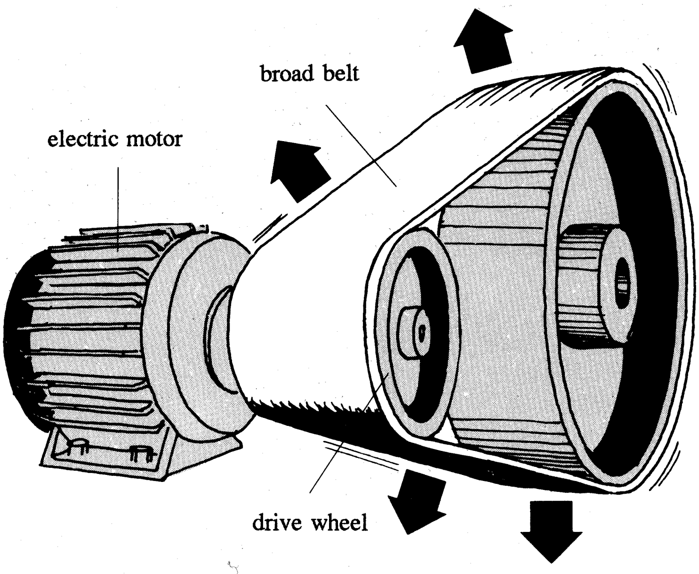
When a plate is set into vibration, excess air pressure forms on one side of the plate and then the other. Sound comes from both sides. The pressure difference balances out close to the edges so that the radiation there is slight. Thus, a long, narrow plate radiates less sound than a square plate.

Principle



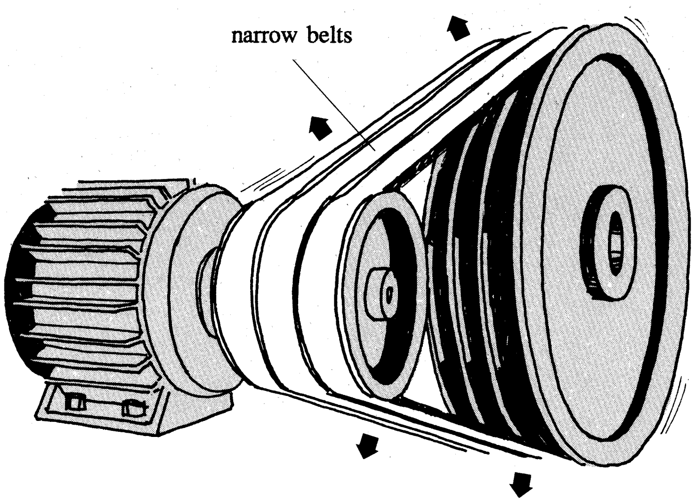


Application with drive belts



Example

A belt drive creates a large amount of low frequency noise because of the vibration of the broad belt.



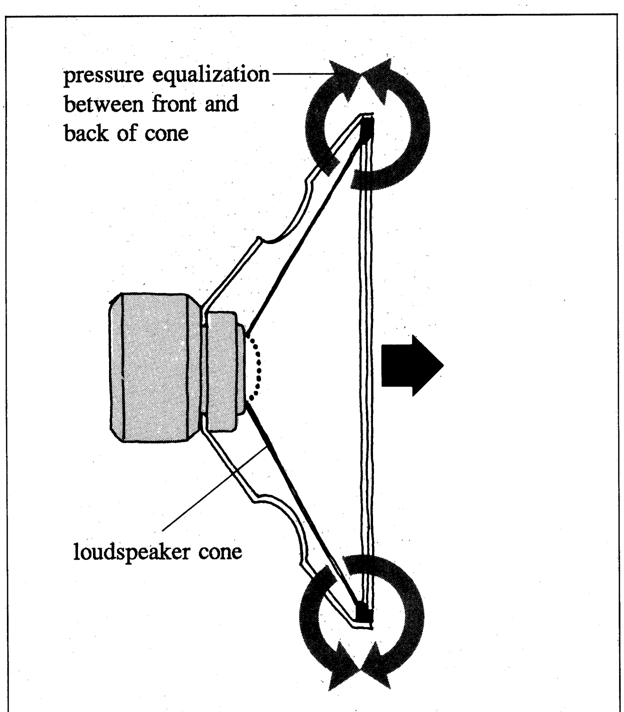
Control Measure

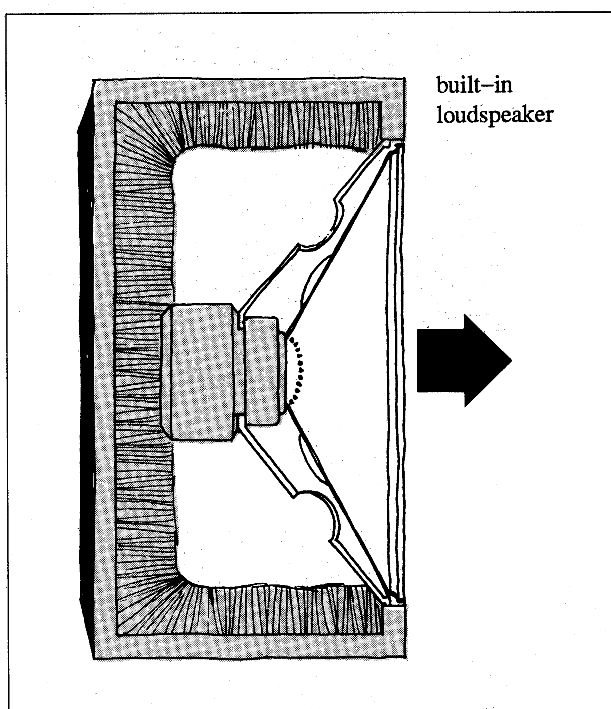
The broad drive belt is replaced by narrower belts separated by spacers. This reduces the noise radiated.

PLATES WITH FREE EDGES PRODUCE LESS LOW FREQUENCY NOISE

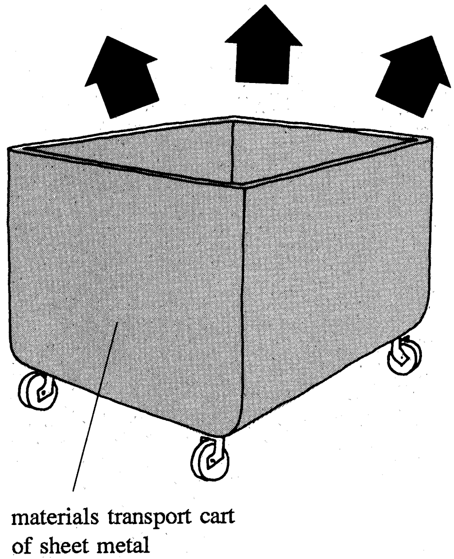
If a plate vibrates with free edges, pressure equalization takes place between the two sides of the plate, thus reducing sound emissions. Enclosing the corners prevents pressure equalization and the sound emission is greater, especially at low frequencies. For example, loudspeakers produce more bass if they are enclosed in a cabinet.

Principle





Application of transporting materials

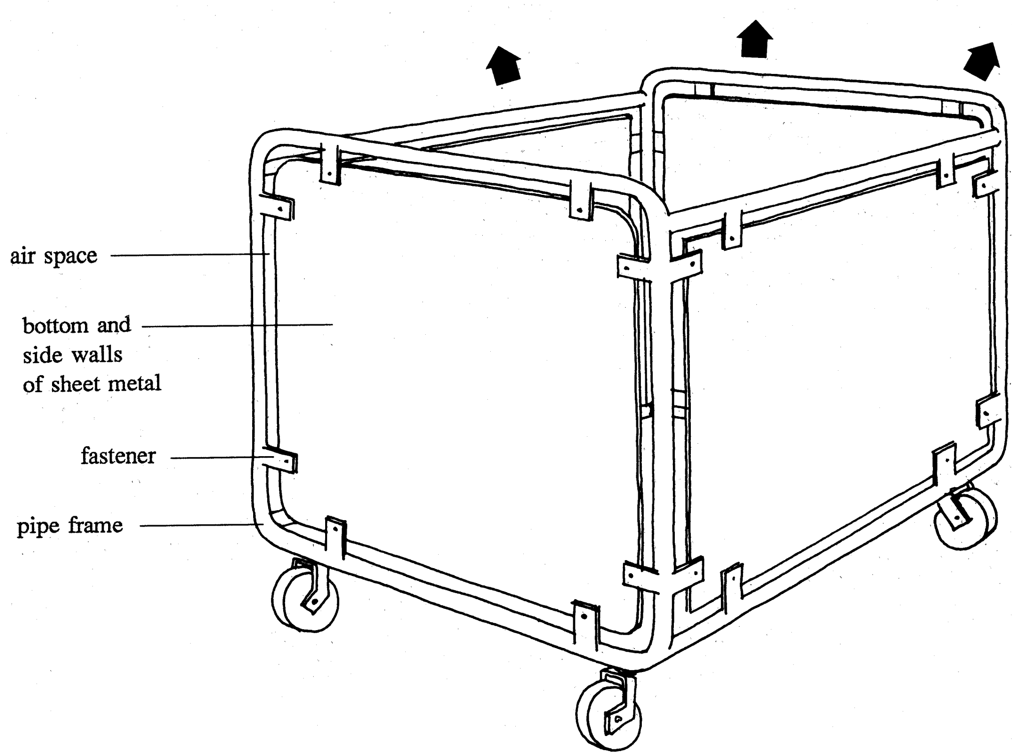


Example

Bumps in the floor produce noise from the bottom and side plates of a cart when the cart is pushed. Sound is also emitted when material strikes the bottom of the plate. Pressure equalization only takes place at the top edges of the side plates.

Control Measure

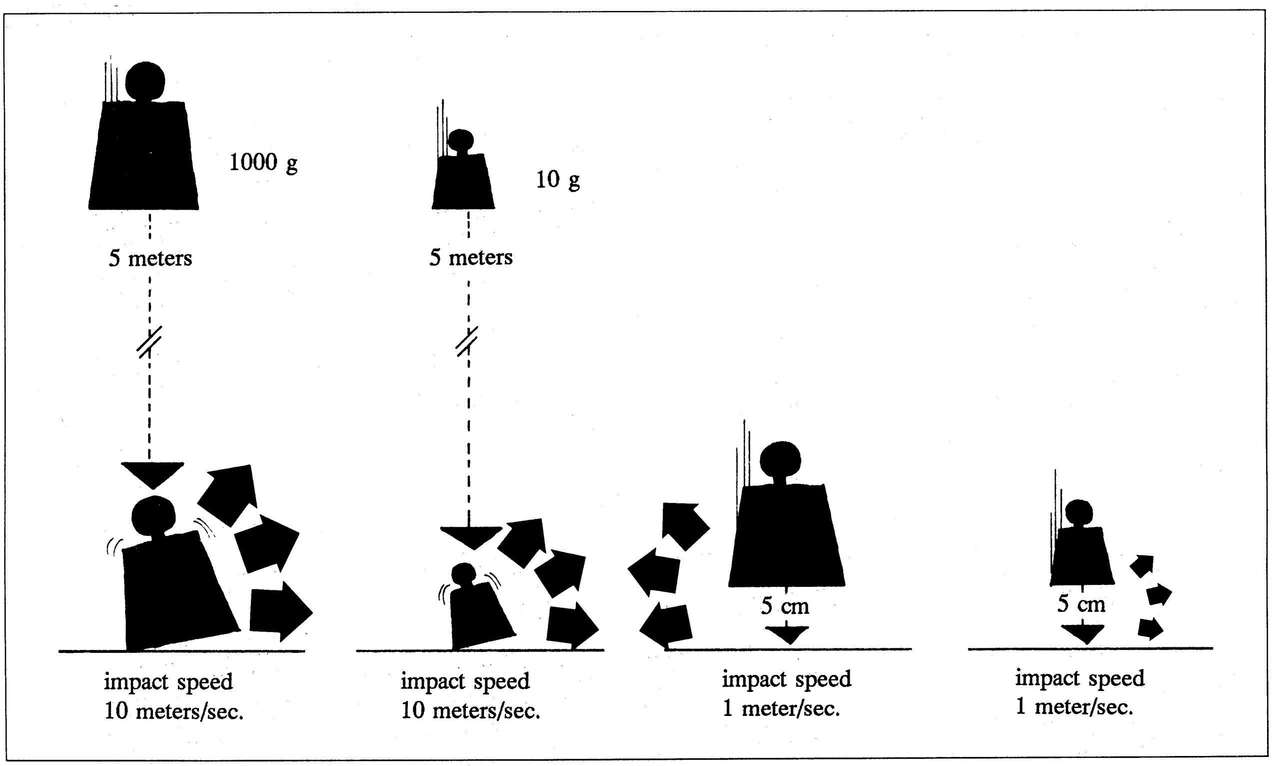
The walls are replaced by new ones constructed with a pipe frame. Plates are fastened with a gap between the plates and the frame. Pressure equalization takes place along all the edges, and the low frequency noise is reduced.

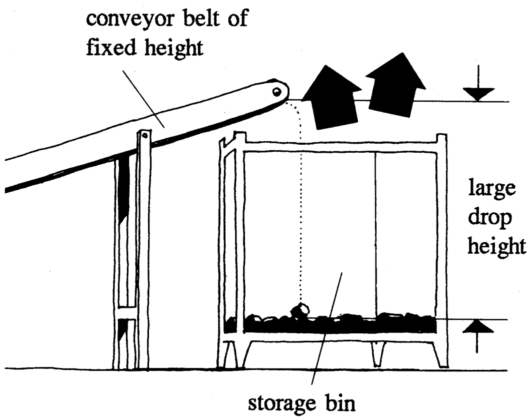


LIGHT OBJECTS AND LOW SPEED PRODUCE THE LEAST IMPACT NOISE

When a plate is struck by an object, the plate vibrates and makes noise. The sound level is determined by the weight of the object and its striking speed. If the drop height of an object is reduced from 5 meters to 5 centimeters, or if the weight is reduced from 1000 g to 10 g, the sound level drops by about 20 dB.

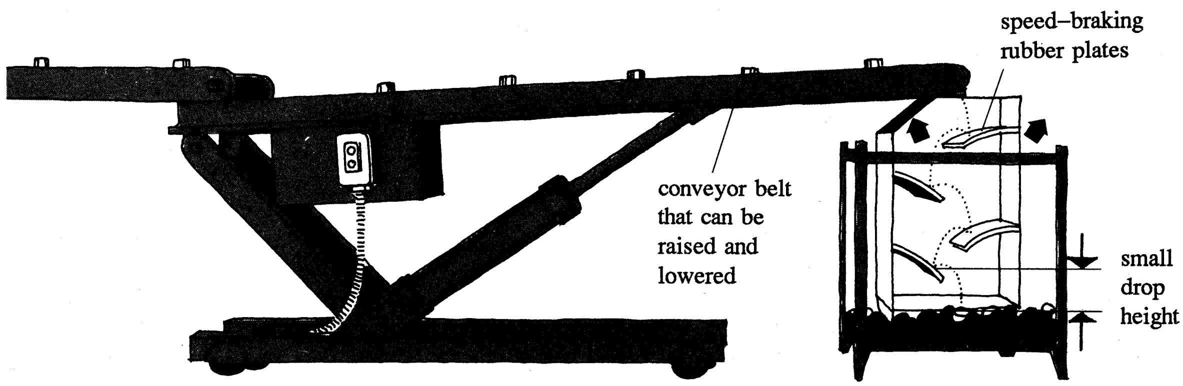
Principle

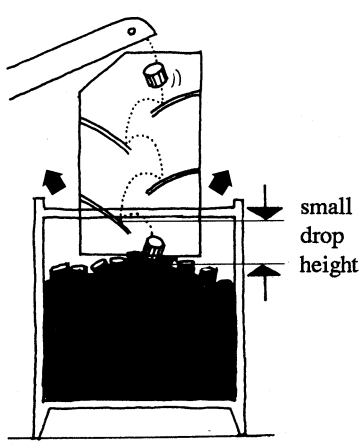




Example

Steel parts are transported from a machine to a storage bin. When the bin is empty, the drop height is large and the noise is loud.





Control Measure

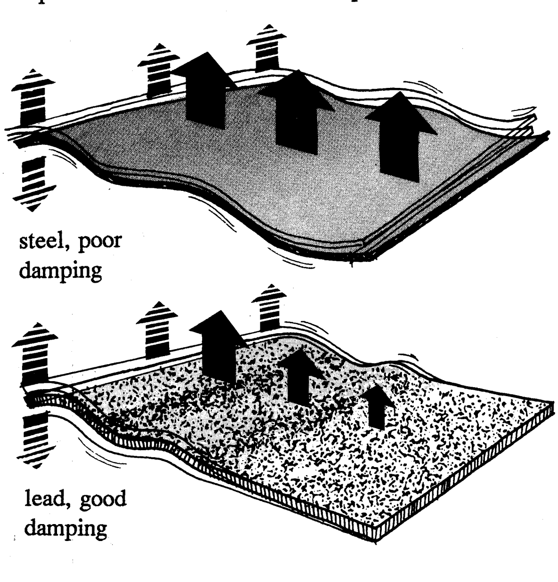
A hydraulic system is installed so that the conveyor belt can be raised and lowered. The belt ends in a drum equipped with rubber plates to break the fall of the parts. The drum is raised automatically

A DAMPED SURFACE PRODUCES LESS SOUND

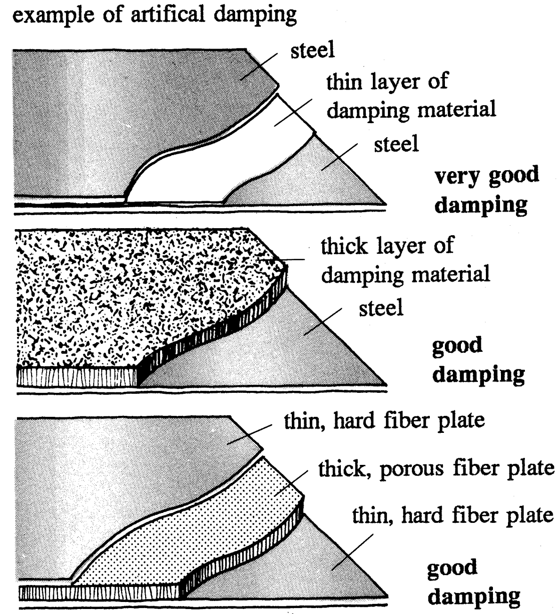
As vibration moves across a plate, it gradually decreases as it travels, but, in most plates, this reduction is rather small. In such cases, the material is said to have low internal damping. Internal damping in steel, for example, is extremely poor. Good damping can be achieved by adding coatings or intermediate layers with better internal damping.

Principle

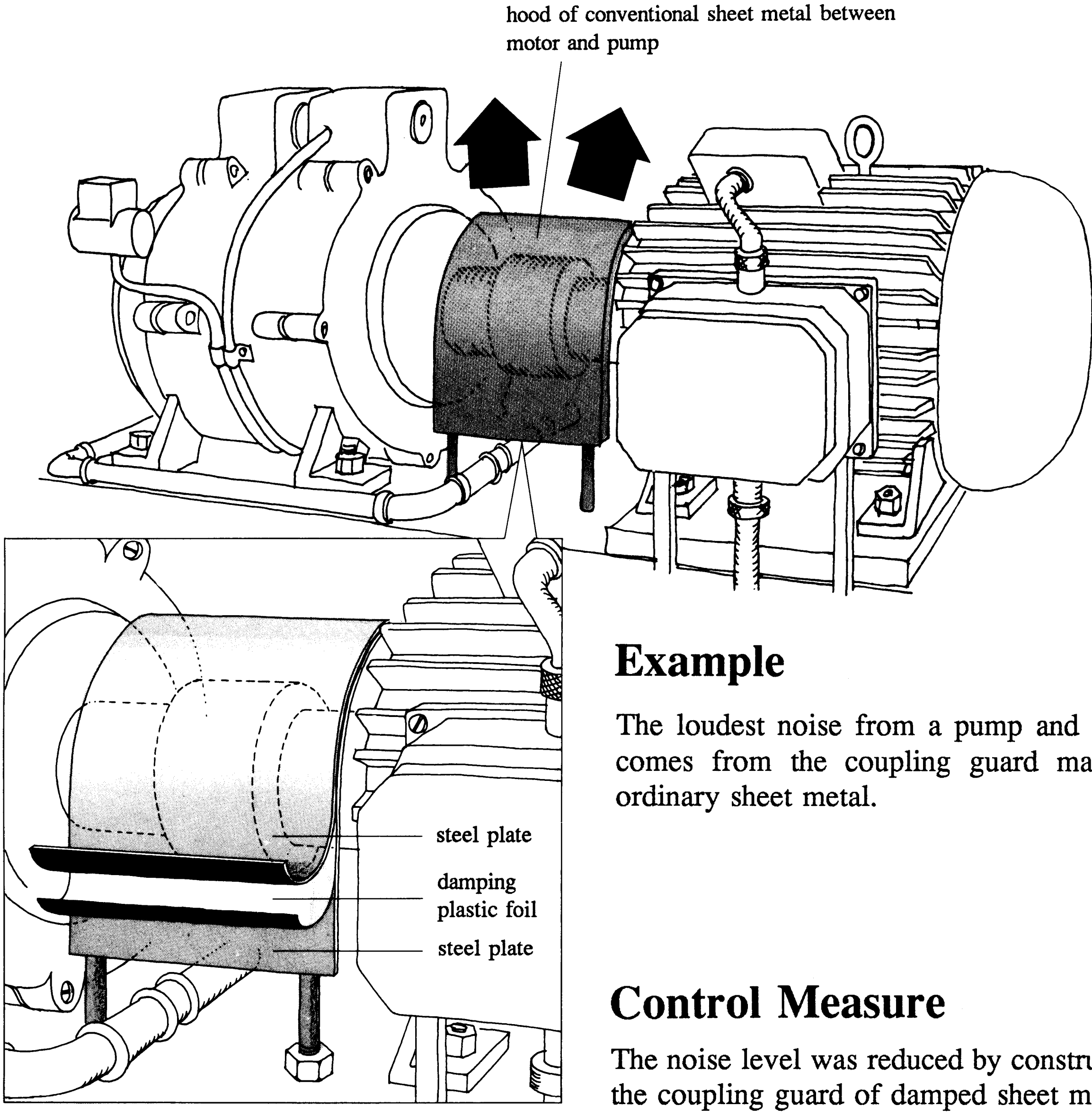
example of vibration movement in a plate



example of artifical damping



Application of hoods and protective covers



Example

The loudest noise from a pump and motor comes from the coupling guard made of ordinary sheet metal.

Control Measure

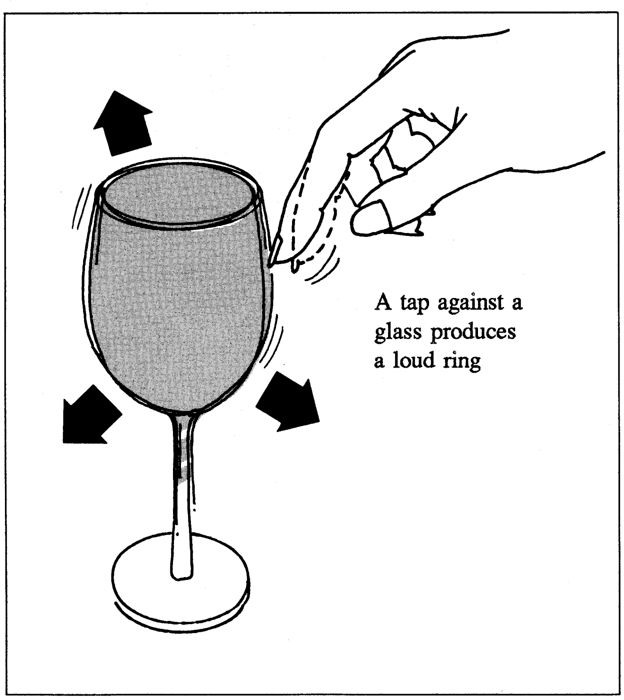
The noise level was reduced by constructing the coupling guard of damped sheet metal.

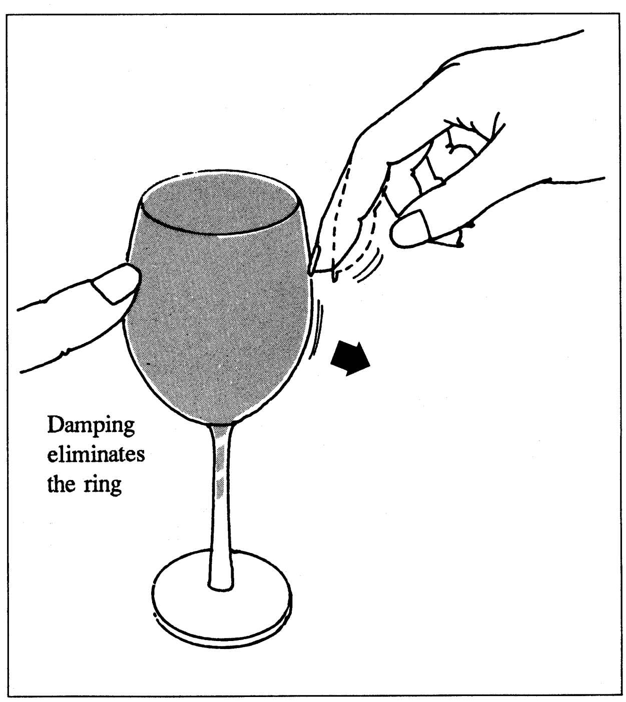
RESONANCE AMPLIFIES NOISE BUT IT CAN BE DAMPED

Resonance greatly increases noise from a vibrating plate, but it can be suppressed or prevented by damping the plate.

It may often be sufficient to damp only part of the surface, and, in some rare cases, damping of a single point is effective.

Principle





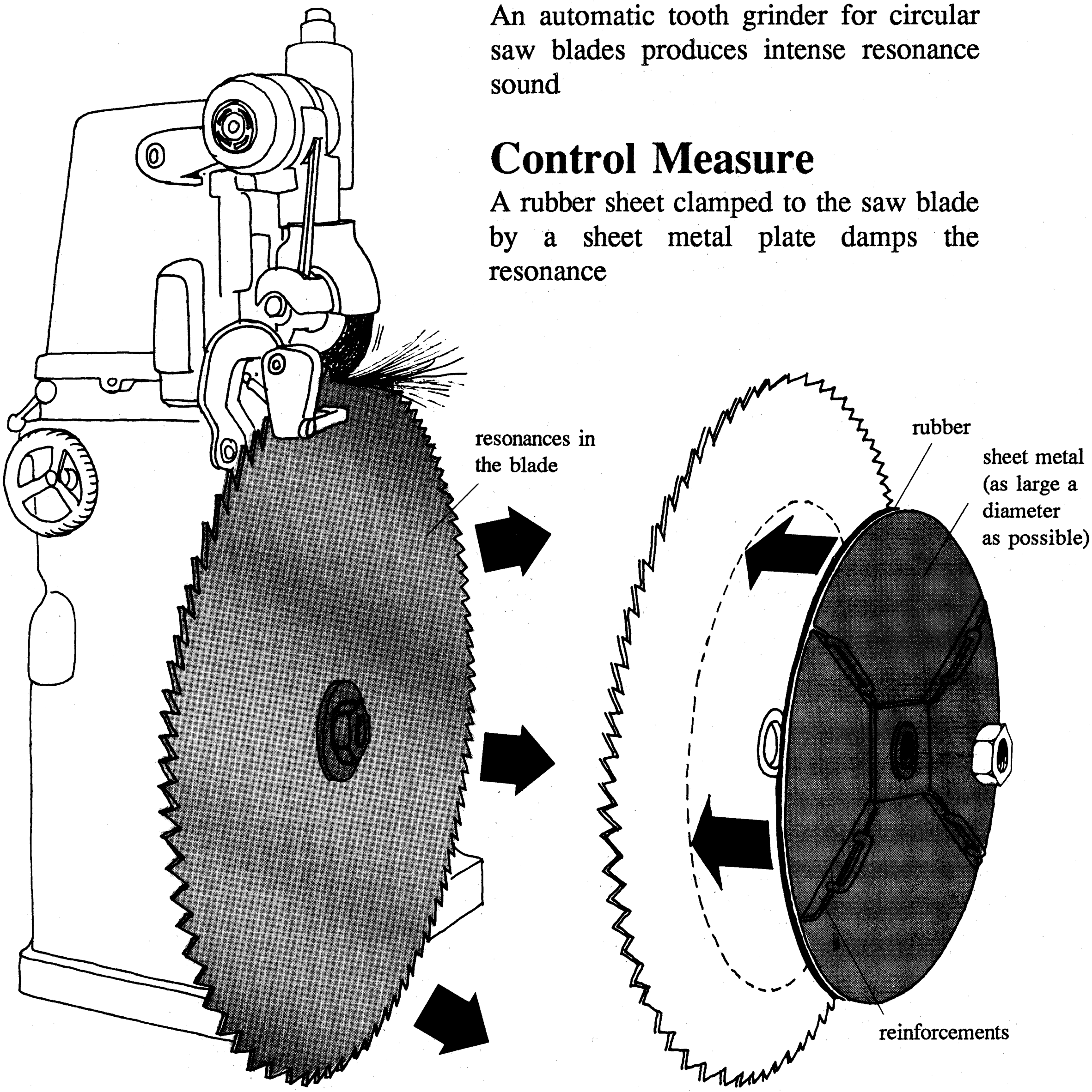
Application to metal working

Example

An automatic tooth grinder for circular saw blades produces intense resonance sound

Control Measure

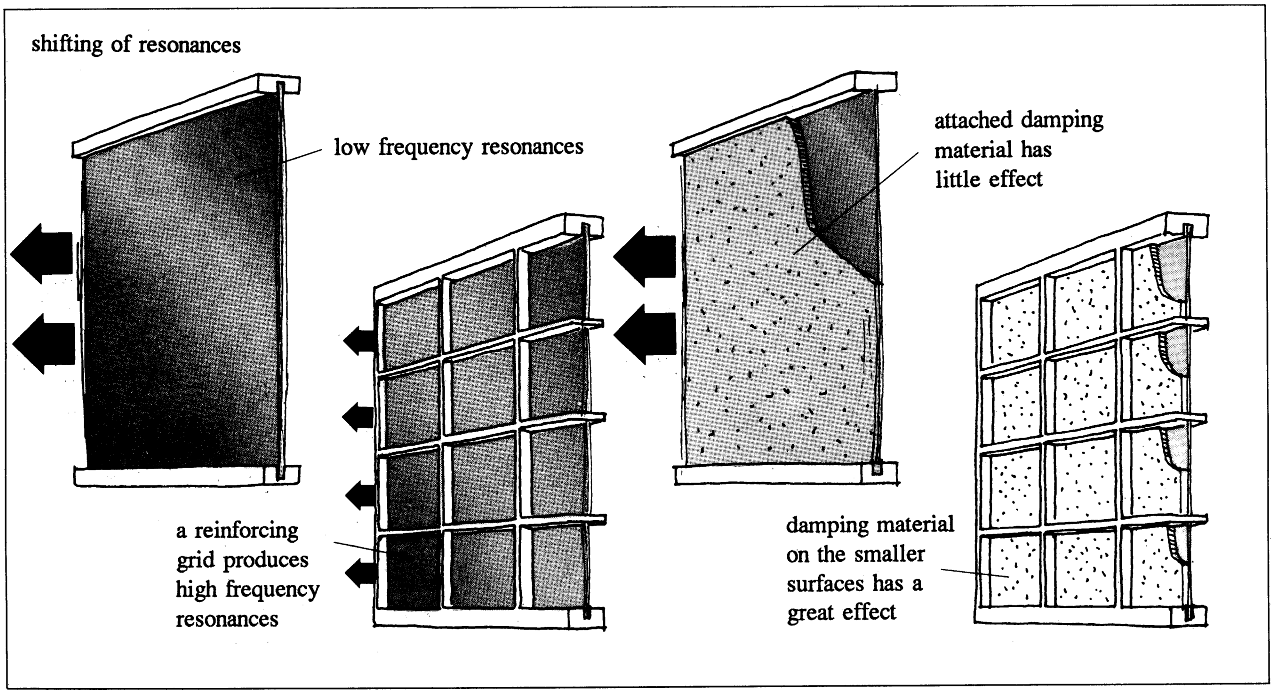
A rubber sheet clamped to the saw blade by a sheet metal plate damps the resonance



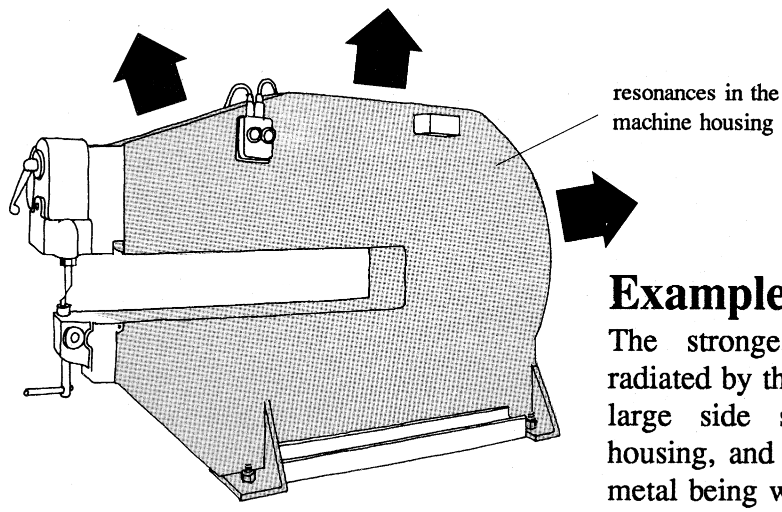
RESONANCE SHIFTED TO HIGHER FREQUENCY IS MORE EASILY DAMPED

Large vibrating plates often have low frequency resonances which can be difficult to damp. If a plate is stiffened, the resonances are shifted to higher frequencies which can be more easily damped.

Principle



Application to a machine housing

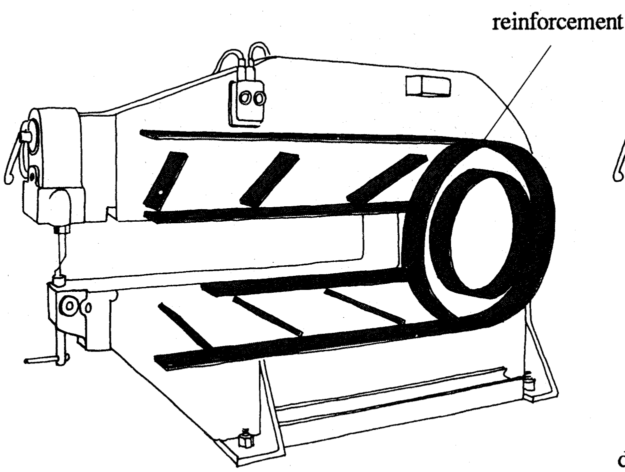


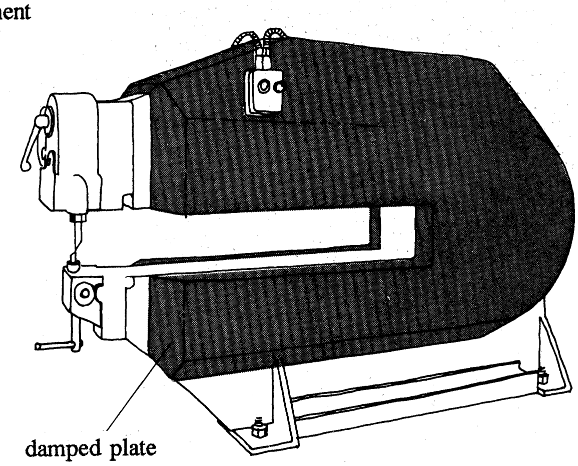
Example

The strongest low frequency sound radiated by this machine comes from the large side surfaces of the machine housing, and not, as expected, from the metal being worked.

Control Measure

The sheet metal sides of the housing are stiffened with metal straps. A damped plate (total thickness 2 mm) is installed over the straps.

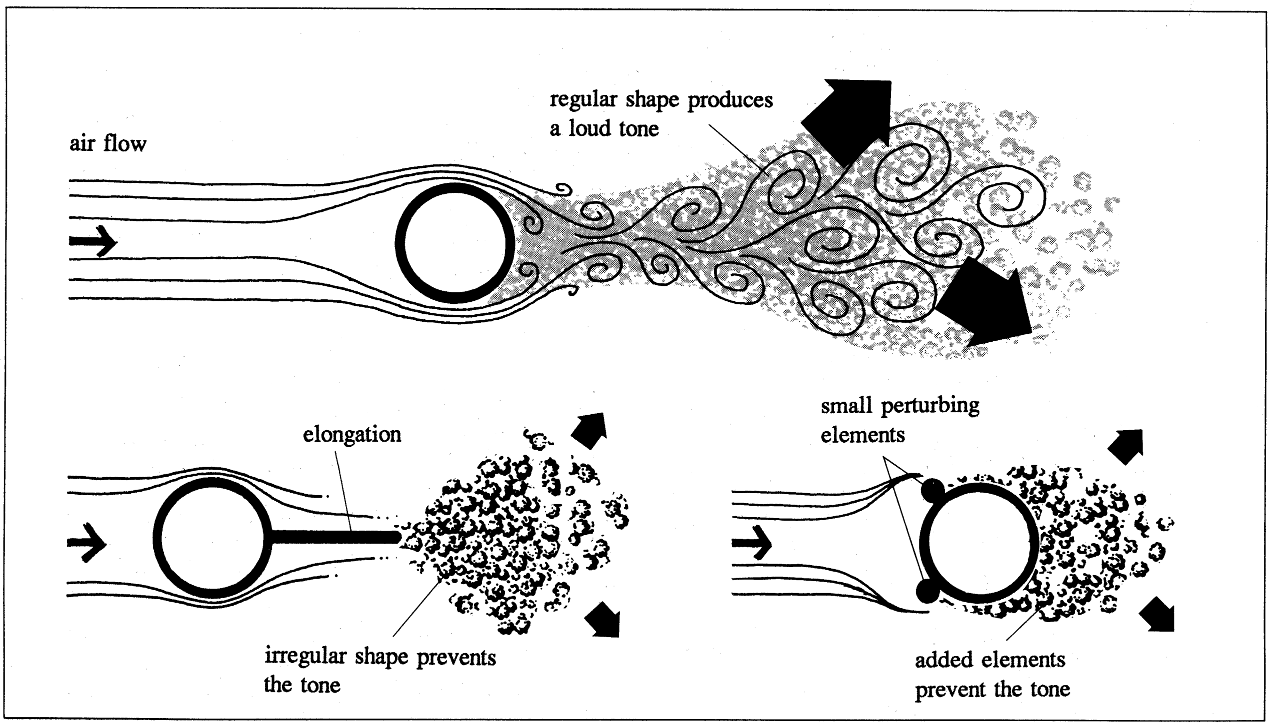




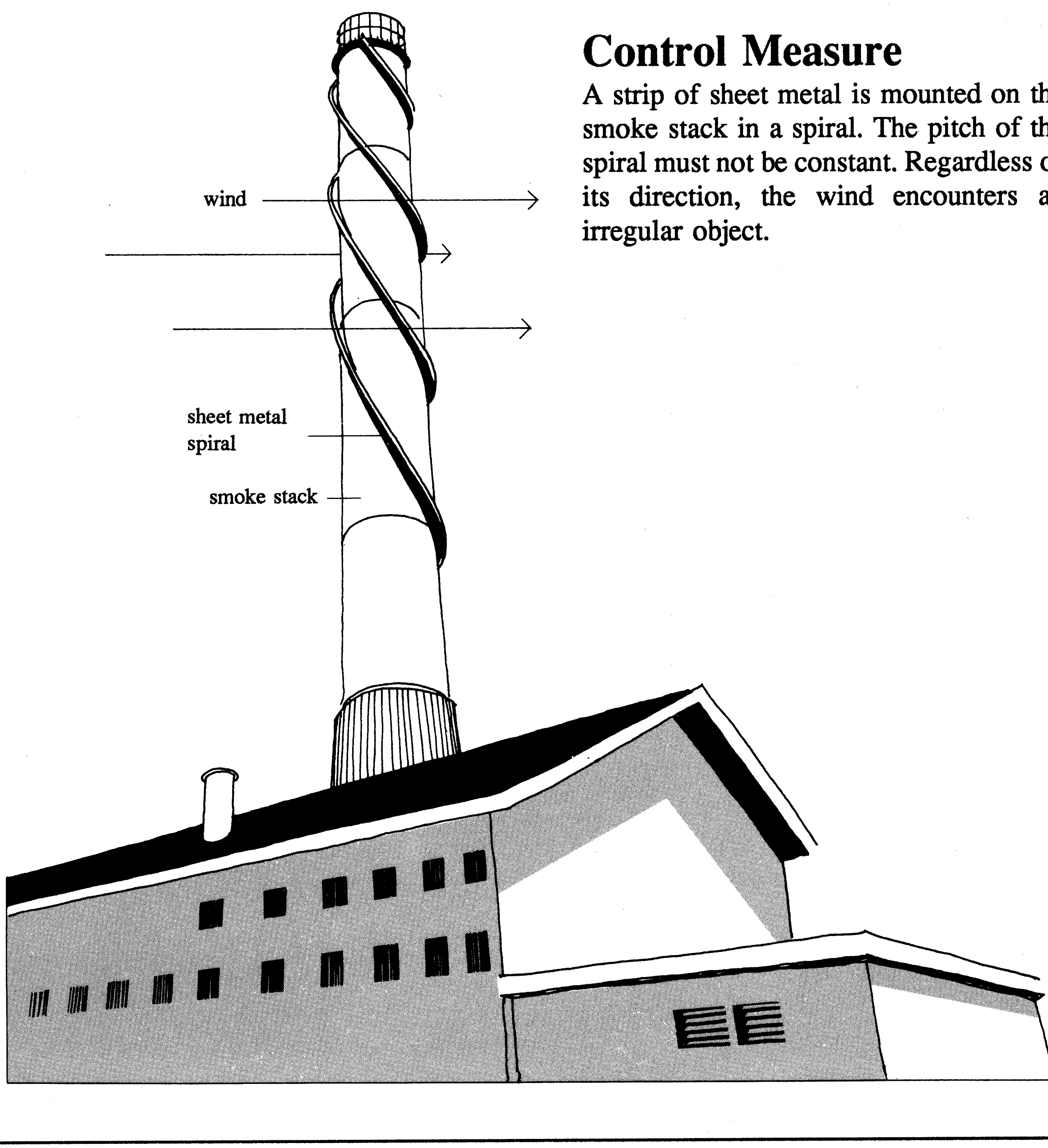
WIND TONES CAN BE ELIMINATED

When air passes by an object at certain speeds, a strong pure tone, known as a Karman tone, can be produced. This tone can be prevented by making the object longer in the direction of flow, such as with a "tail," or by making the object's shape irregular.

Principle



Application with wind currents



Example

At certain wind speeds, loud sounds can be produced by a smoke stack.

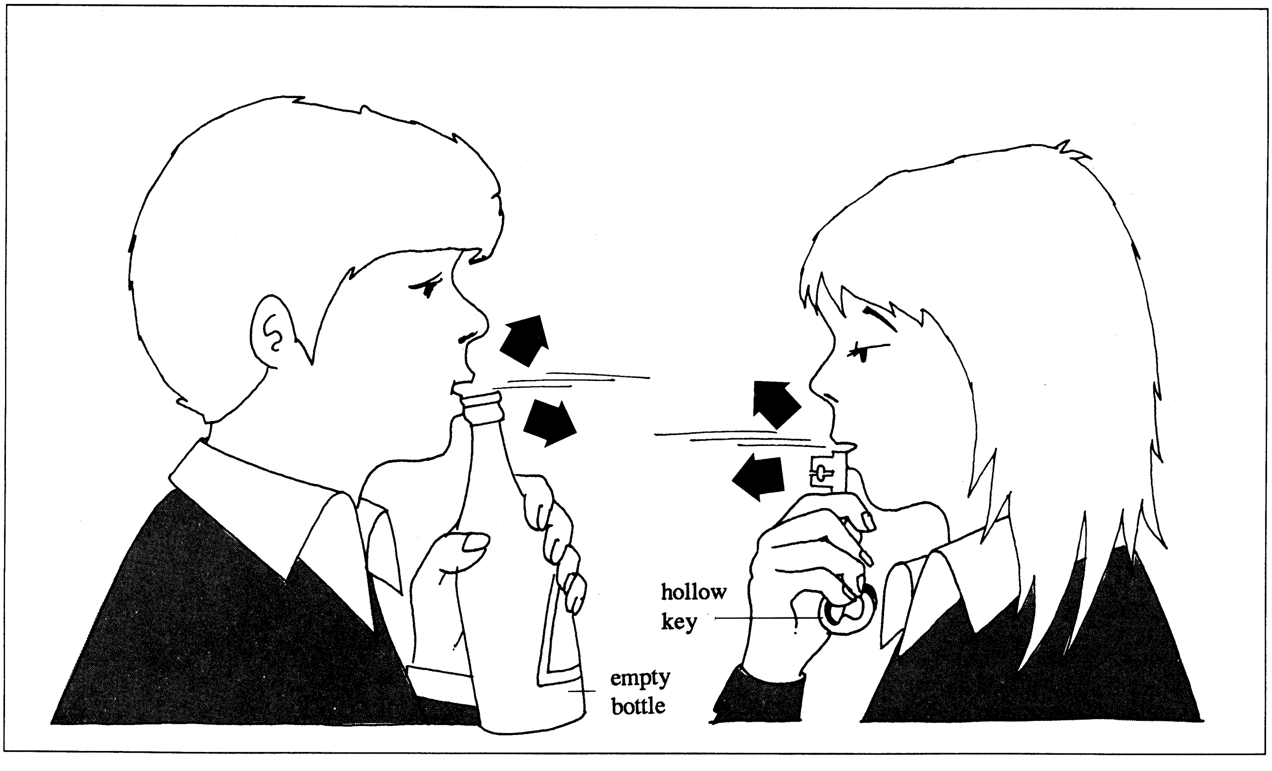
Control Measure

A strip of sheet metal is mounted on the smoke stack in a spiral. The pitch of the spiral must not be constant. Regardless of its direction, the wind encounters an irregular object.

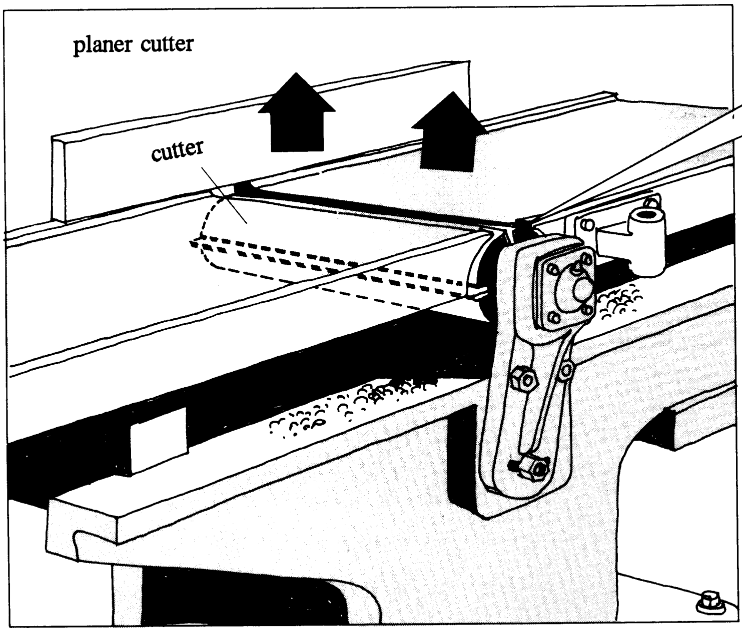
AIR FLOW PAST HOLLOW OPENINGS SHOULD BE AVOIDED

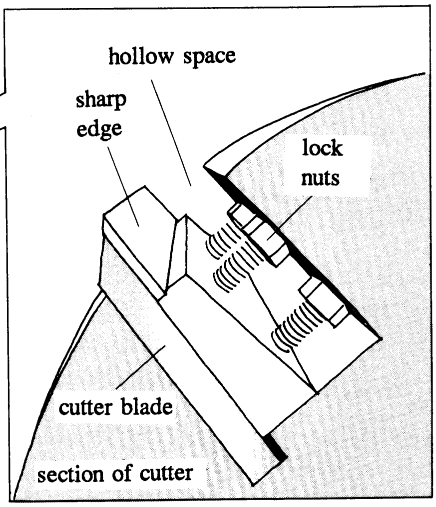
When air or another gas is blown at certain speeds across the edges of an opening to a cavity, loud pure tones are generated. This is how wind instruments operate. The greater the volume of the cavity and the smaller the opening, the lower the frequency will be.

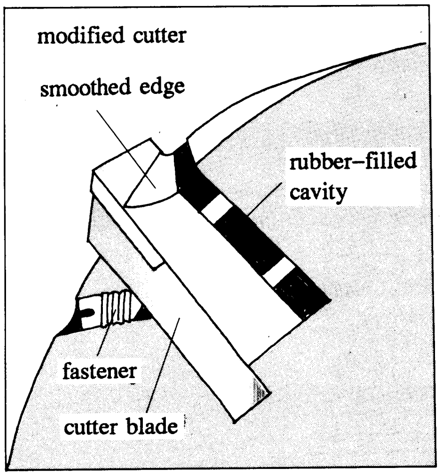
Principle



Application with air and steam jets/objects in rapid motion







Example

When a cutter wheel revolves under no–load conditions, strong pure tones can arise from the track for holding the cutter blade. Eddies at the blade edge generate narrow band noise. Some of the frequencies in the narrow band noise may be amplified by a cavity resonance.

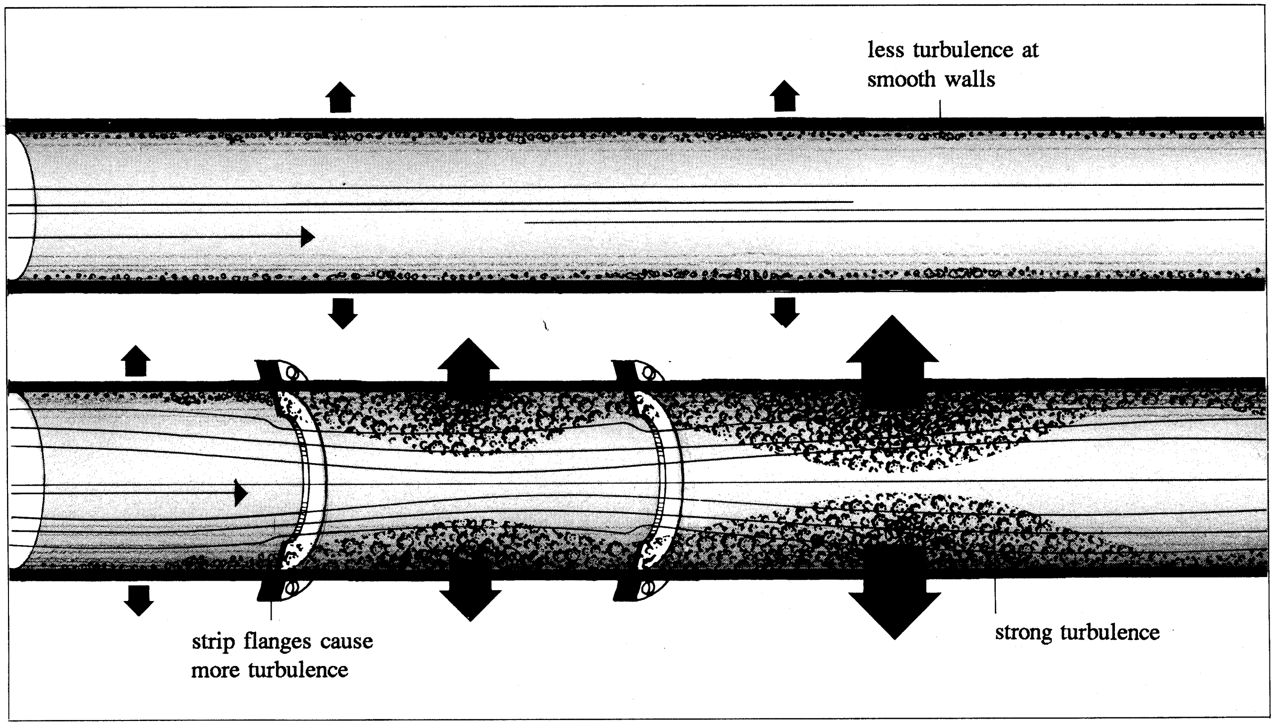
Control Measure

Smoothing the cutter edge and filling the empty space may reduce the broad band noise and may also eliminate the pure tones.

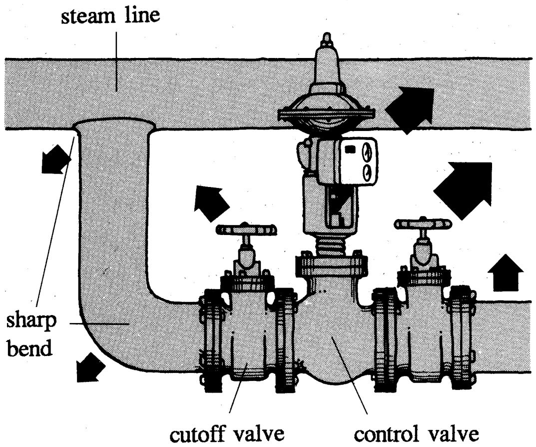
DUCTS WITHOUT OBSTRUCTIONS PRODUCE THE LEAST AMOUNT OF NOISE FROM TURBULENCE

When there is flow in ducts or pipes, there is always some turbulence at the duct walls. The noise from turbulence increases if the flow abruptly changes direction, if the flow speed increases, or if objects partially block the flow.

Principle



Application with a piping system

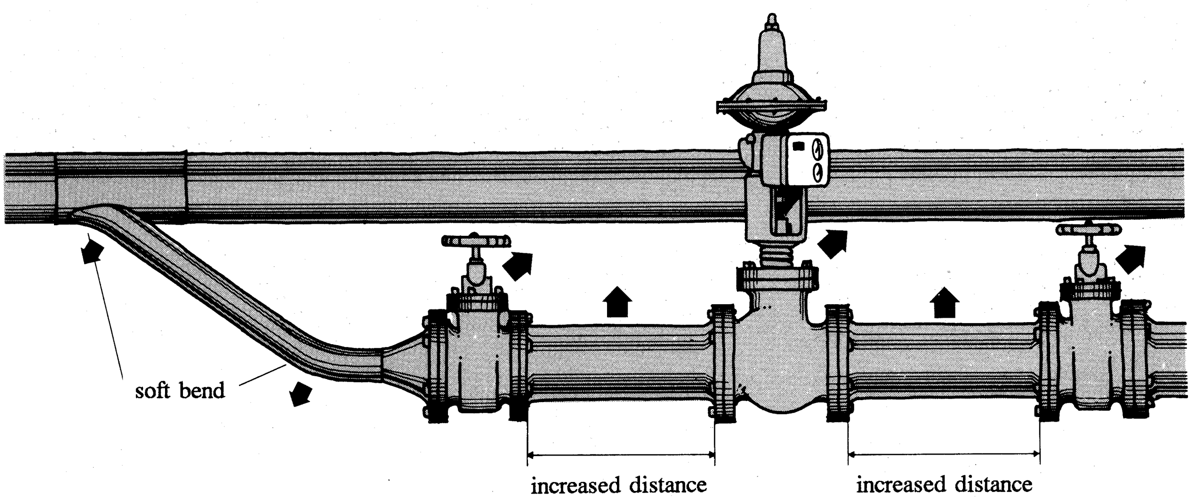


Example

A branch of a steam line has three valves which produce a loud shrieking sound. The branch has two sharp bends which also produce a lot of noise.

Control Measure

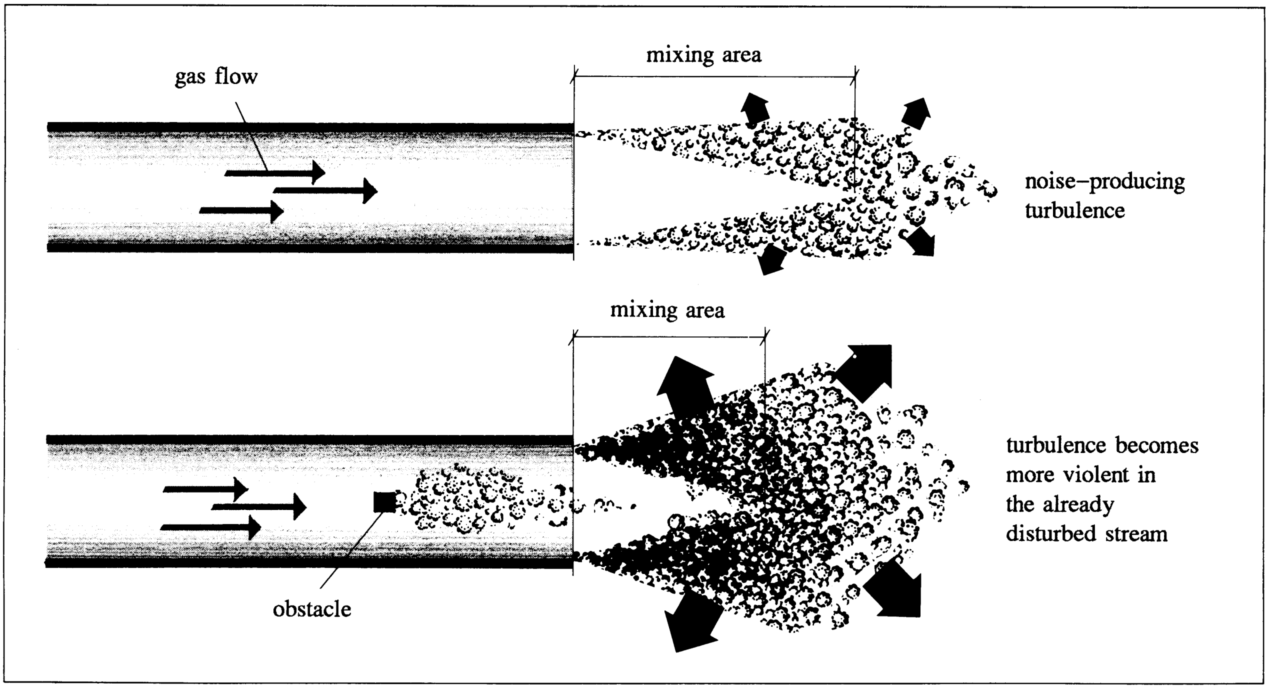
A new branch is created with more gradual bends. Pieces of tubing are placed between each valve so that turbulence is reduced or eliminated before the stream reaches the valve.



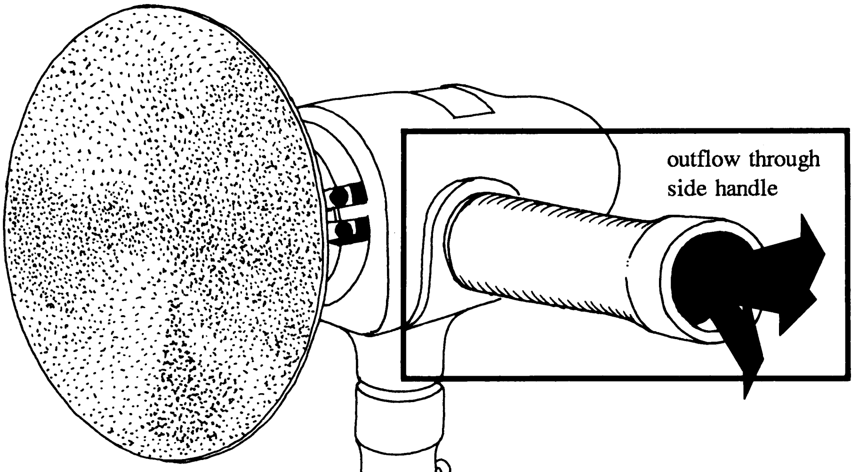
UNDISTURBED FLOW PRODUCES THE LEAST AMOUNT OF EXIT NOISE

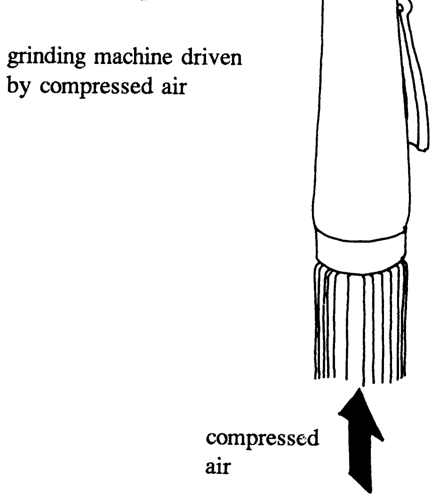
When a flowing gas mixes with a non–moving gas, noise may be produced, especially if the flow is disturbed before it reaches the outlet. A lower exit speed will produce a lower sound level. For speeds below 100 meters/second, reduction of the speed by one–half results in a decrease in the noise level of about 15 dB.

Principle



Application of venting compressed air





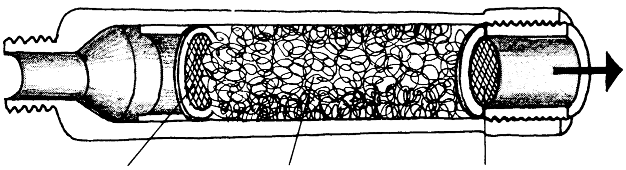
Example

The exhaust air from a grinding machine driven by compressed air produces a loud noise. The air becomes turbulent upon leaving the grinding machine through the side handle.

Control Measure

A new handle is developed which is filled with a porous sound absorptive material between two fine–mesh gauzes. Passage through the porous material breaks up the turbulence. The air stream leaving the handle is less disturbed, and there is less exhaust noise. A straight lined muffler may also be used.

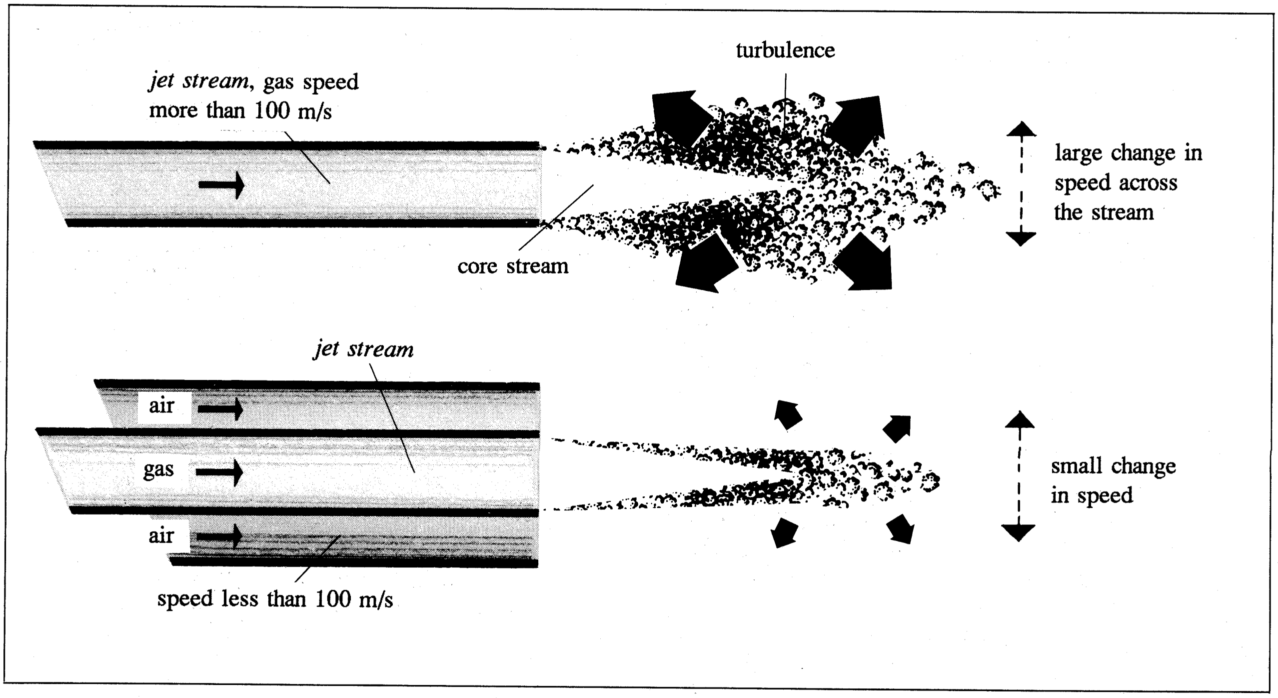
sound–damping handle



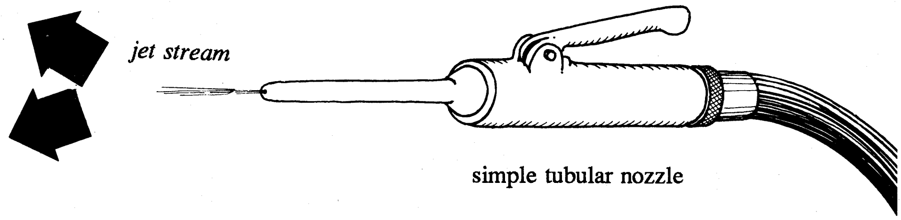
JET NOISE CAN BE REDUCED BY USING AN EXTRA AIR STREAM

The term *jet stream* applies at flow speeds in excess of 100 meters/second. Turbulence at the exit is high. Reducing the exit speed by one half may decrease the noise level by as much as 20 dB. Since the noise level is determined by the speed of the jet stream relative to the speed of the surrounding air, noise emission can be greatly reduced by using an air stream with a lower speed surrounding the jet stream.

Principle

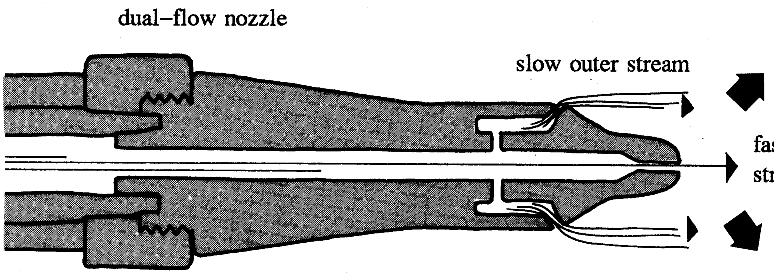


Application with compressed air



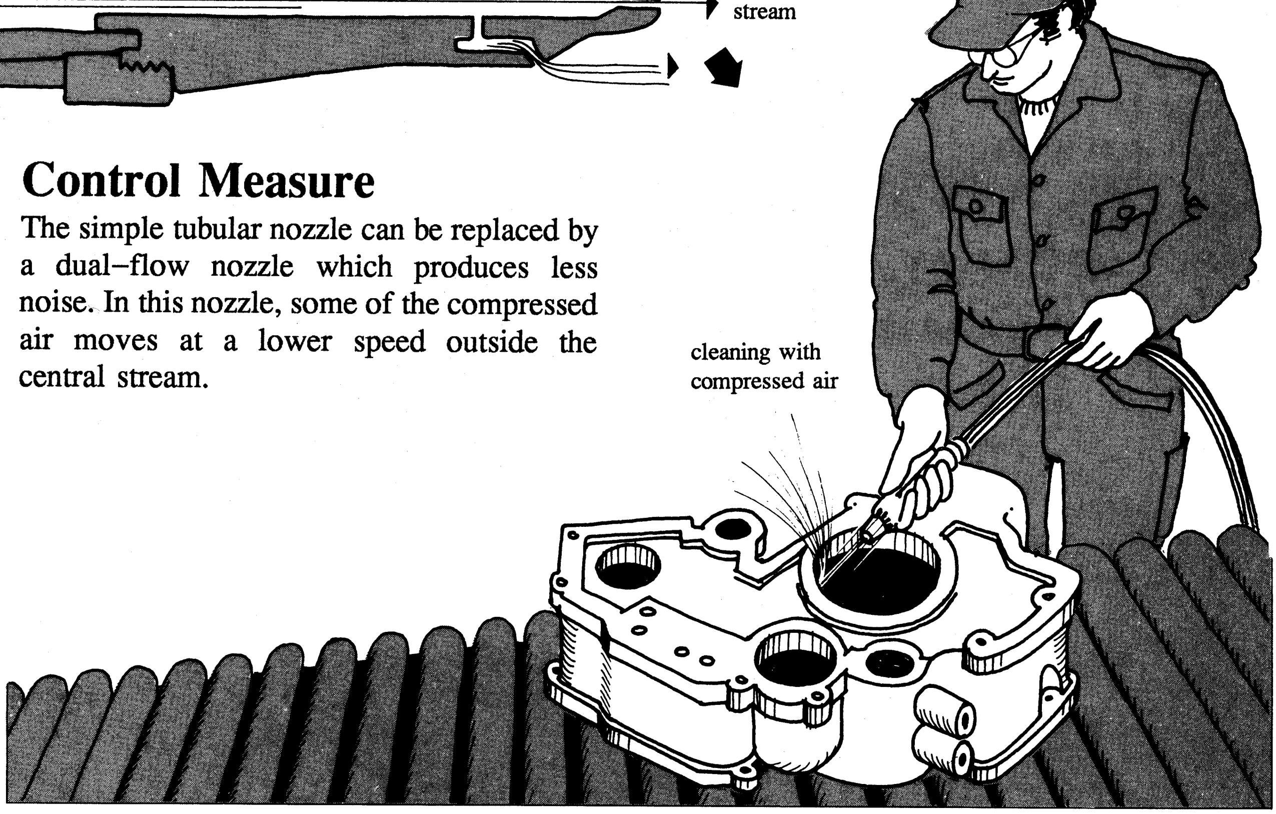
Example

The cleaning of machine parts with compressed air is often carried out with a simple tubular nozzle. Very high exit speeds are required, producing high levels of high–frequency noise.



Control Measure

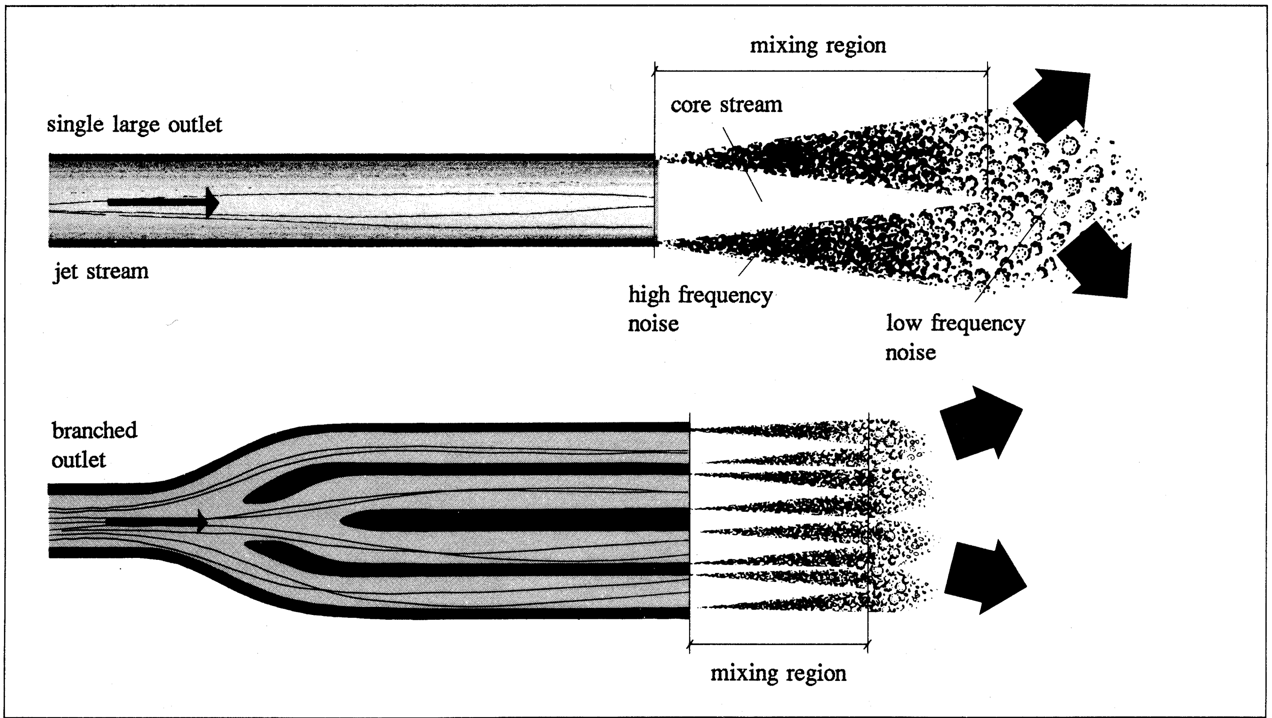
The simple tubular nozzle can be replaced by a dual–flow nozzle which produces less noise. In this nozzle, some of the compressed air moves at a lower speed outside the central stream.



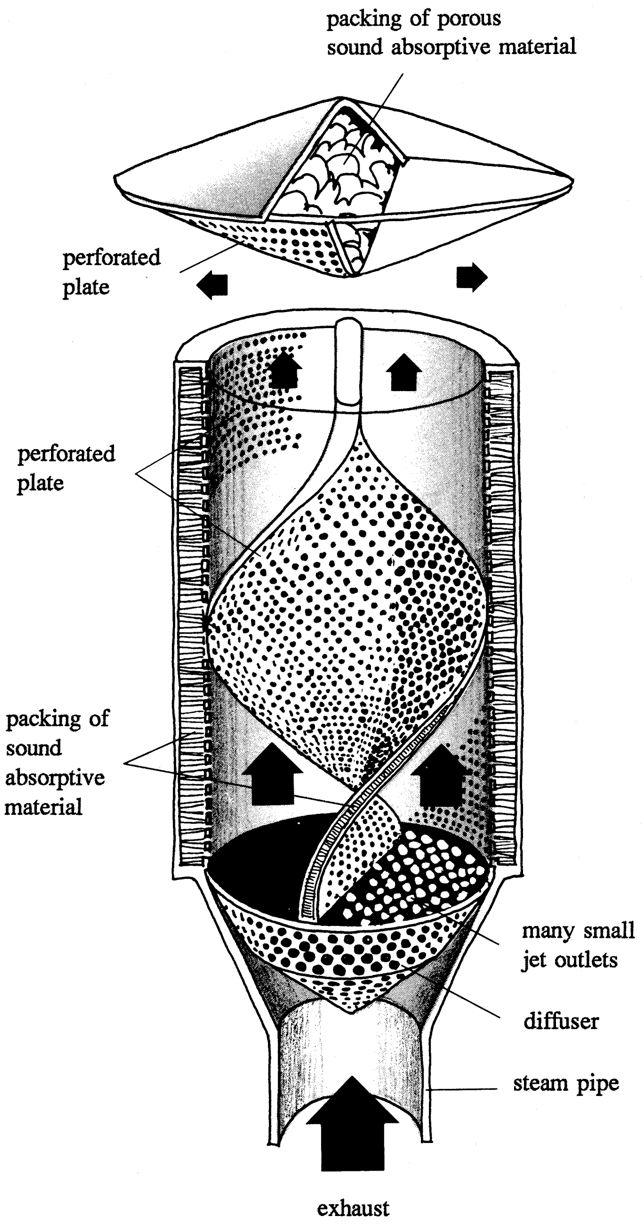
LOW FREQUENCY JET NOISE IS EASIER TO REDUCE IF CONVERTED TO HIGH FREQUENCY

If the diameter of a gas outlet is large, the noise will peak at low frequency. If the diameter is small, the noise will peak at high frequency. The low frequency noise can be reduced by replacing a large outlet with several small ones. The high frequency noise is increased, but this is more easily attenuated.

Principle



Application with compressed air and steam



Example

Steam safety valves in industry sometimes have to discharge very large amounts of steam many times each day. The required large pipes and large outlet speeds produce high level noise with dominating low frequencies. These are disturbing at great distances.

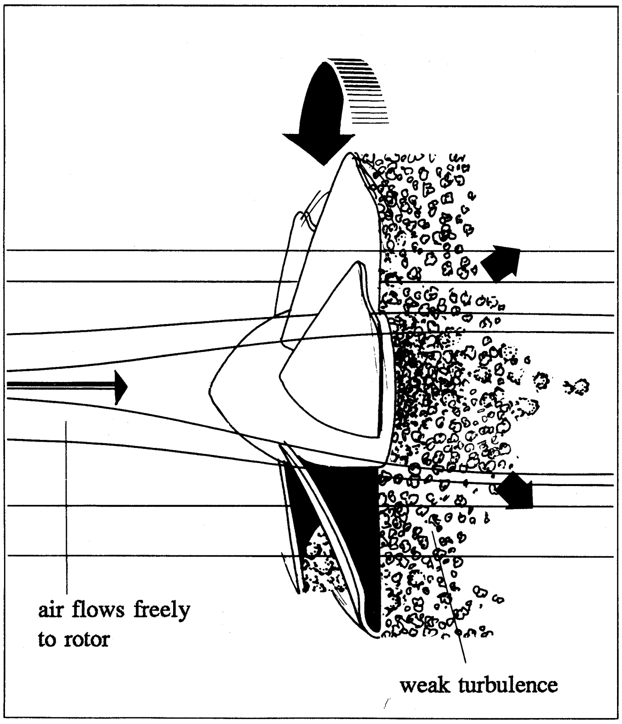
Control Measure

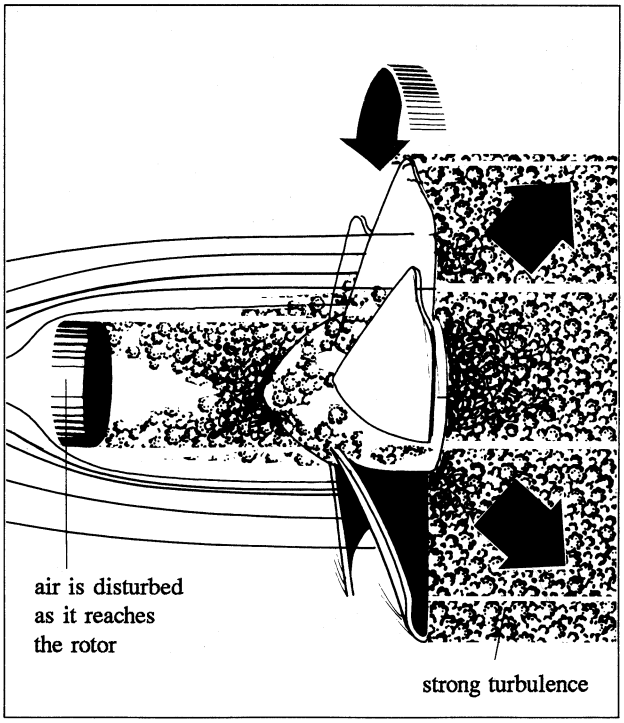
A diffuser in the shape of a perforated cone and a high–frequency muffler with low flow resistance are connected to the steam pipe. The outlet speed is reduced by a factor of four. The total noise emitted is reduced by about 20 dB. The helical muffler absorbs the high–frequency sound generated by the many small holes of the perforated cone.

FANS MAKE LESS NOISE IF PLACED IN SMOOTH, UNDISTRUBED FLOW STREAMS

A fan produces turbulence in air, which causes noise. If turbulence is already present in the incoming air, the sound will be more intense. The same principle applies, for example, to propellers in water.

Principle



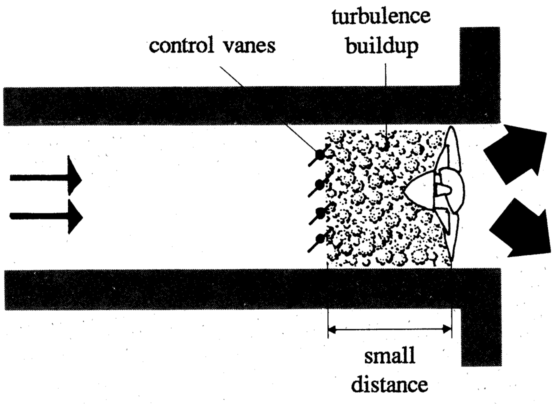


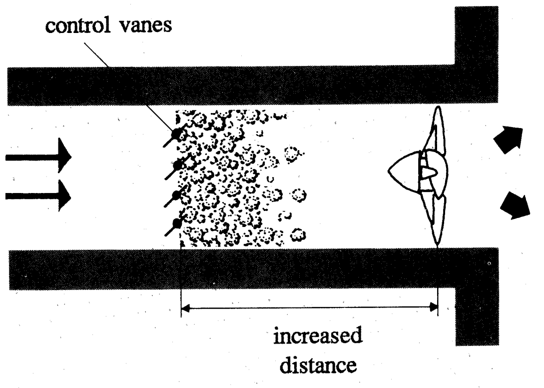
Example

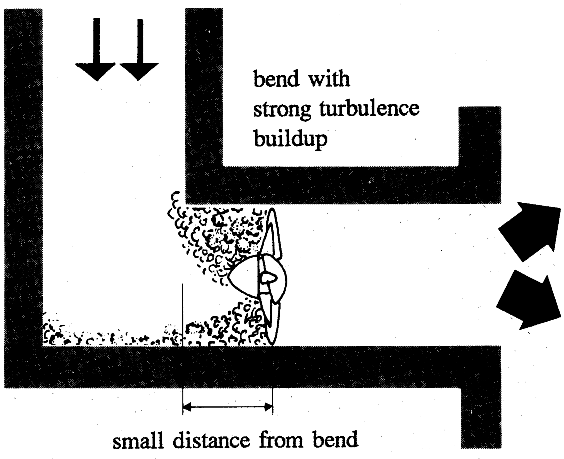
In one case, the fan is located too close to a barrier, and in the other case too close to a sharp bend. The flow is disturbed, and the noise at the outlet is intense.

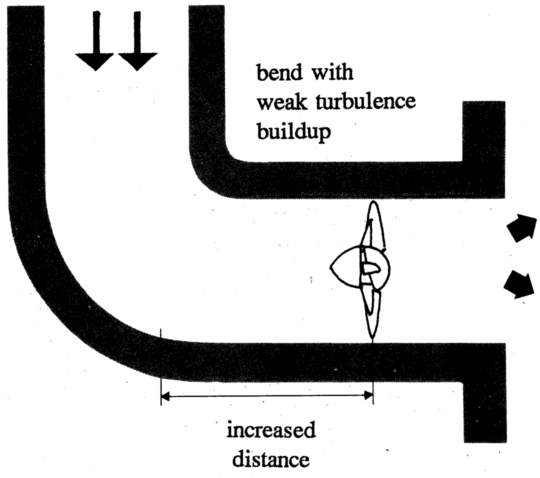
Control Measure

The control vanes are moved further from the fan so that the turbulence has time to die down. In the other case, the bend is made smoother, and the fan is moved away from the bend. Turning vanes could also be used.





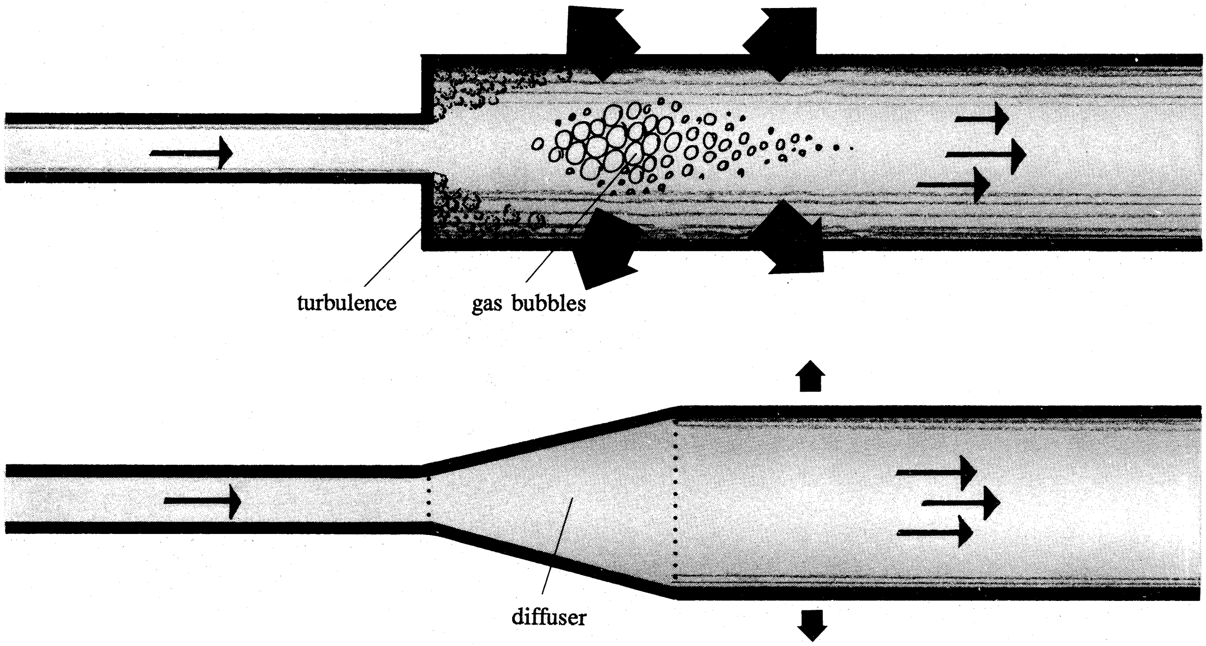




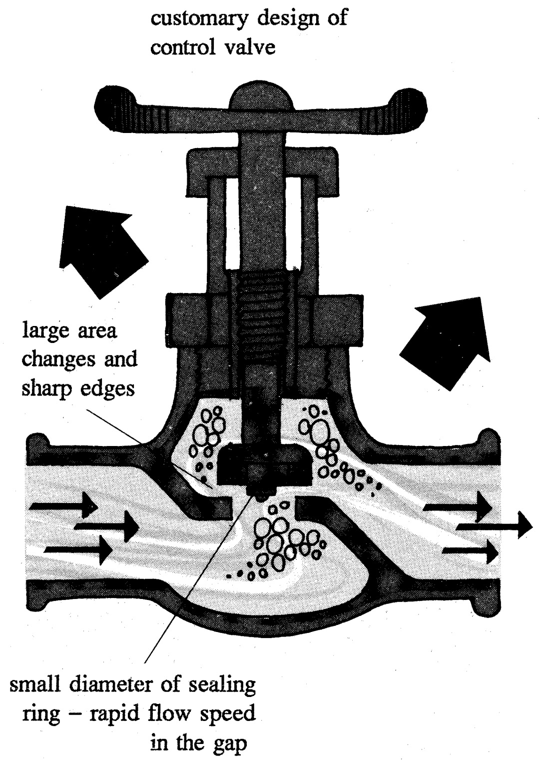
ABRUPT CHANGES IN AREA PRODUCE NOISE

Turbulence will be created if the cross–sectional area liquid–filled pipe increases rapidly, and gas released in the form of bubbles produces a roaring sound. This sound can be reduced by avoiding rapid changes in cross–sectional area within the piping system.

Principle



Application with control valves for liquid systems

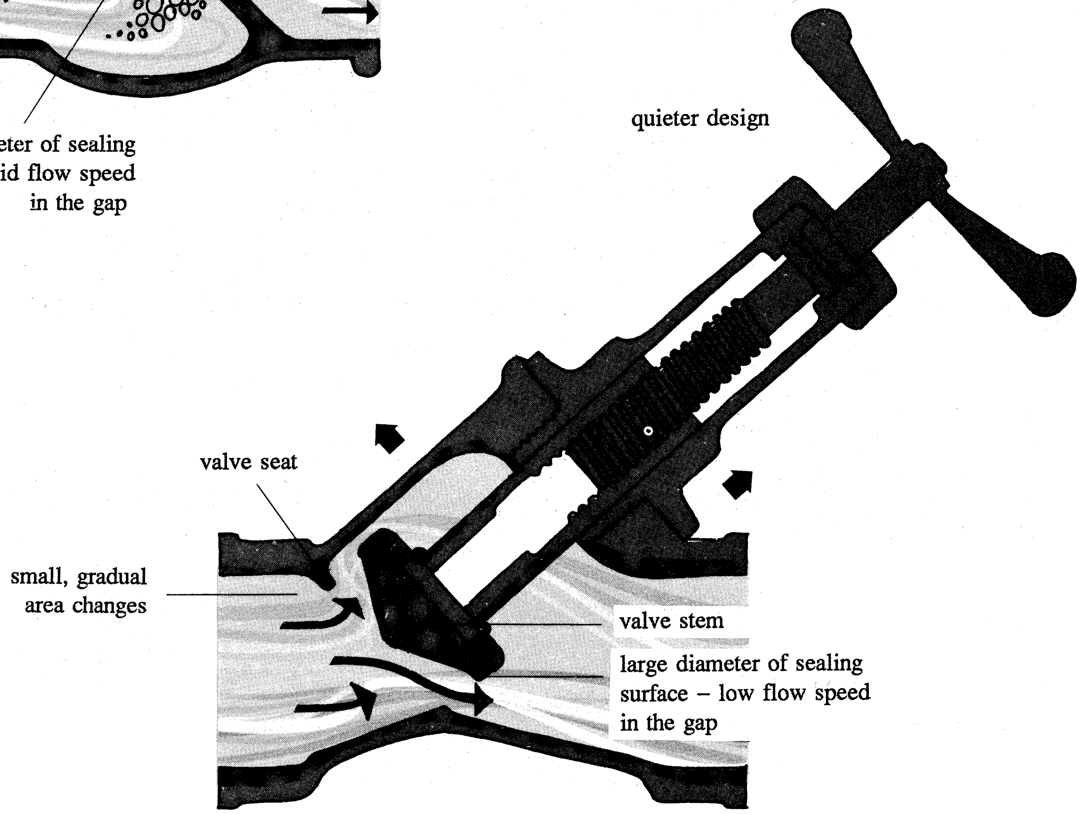


Example

Control valves in liquid systems often have small valve seats with sharp edges and twisted flow paths – resulting in high flow speeds and large pressure changes. The higher the flow speed, the more noise is produced. Air–borne sound is radiated directly by valves and pipes, and solid–borne sound is carried to structural elements nearby and far away.

Control Measure

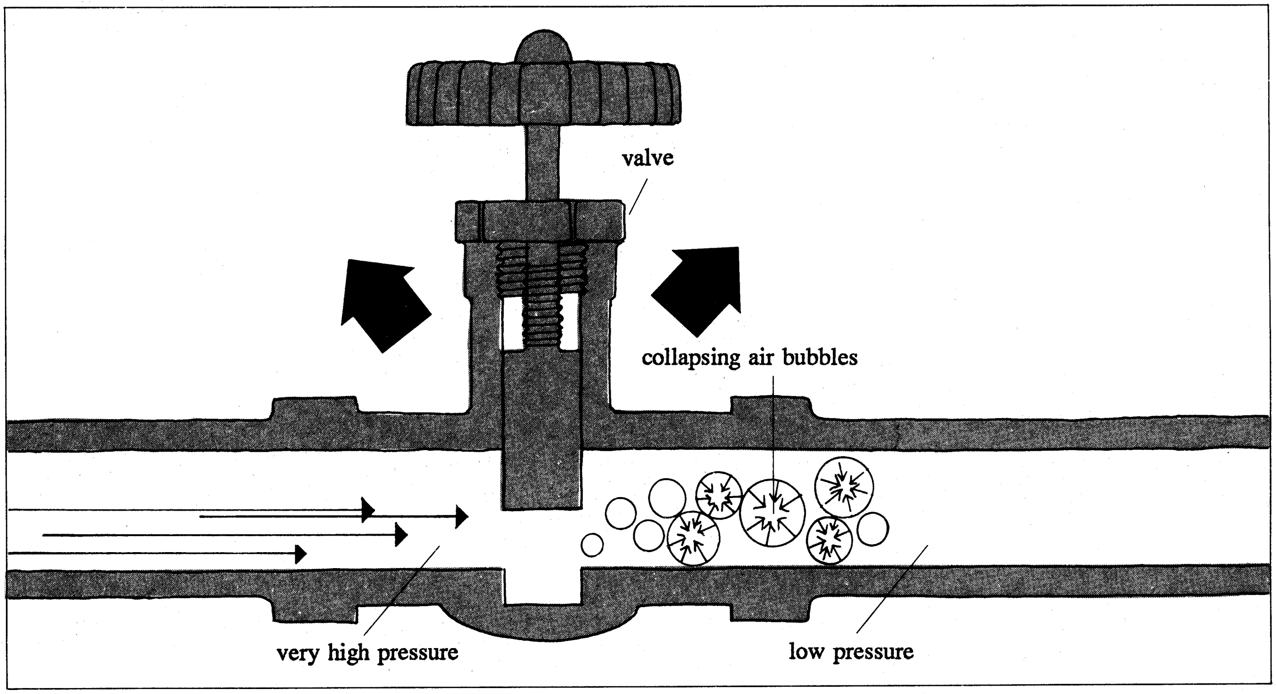
Control valves with larger cone diameters, straighter flow paths, and more rounded edges are used.



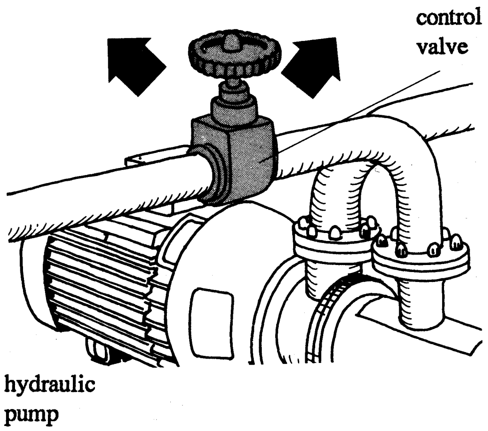
LARGE AND RAPID CHANGES IN PRESSURE PRODUCE "CAVITATION" NOISE

When large pressure drops occur rapidly in liquids, the bubbles produced immediately implode – explode inwards. The result is a roaring noise – and strong vibrations. This so–called cavitation noise is most common in hydraulic systems. Cavitation can be avoided by bringing about the pressure reduction in several small steps.

Principle

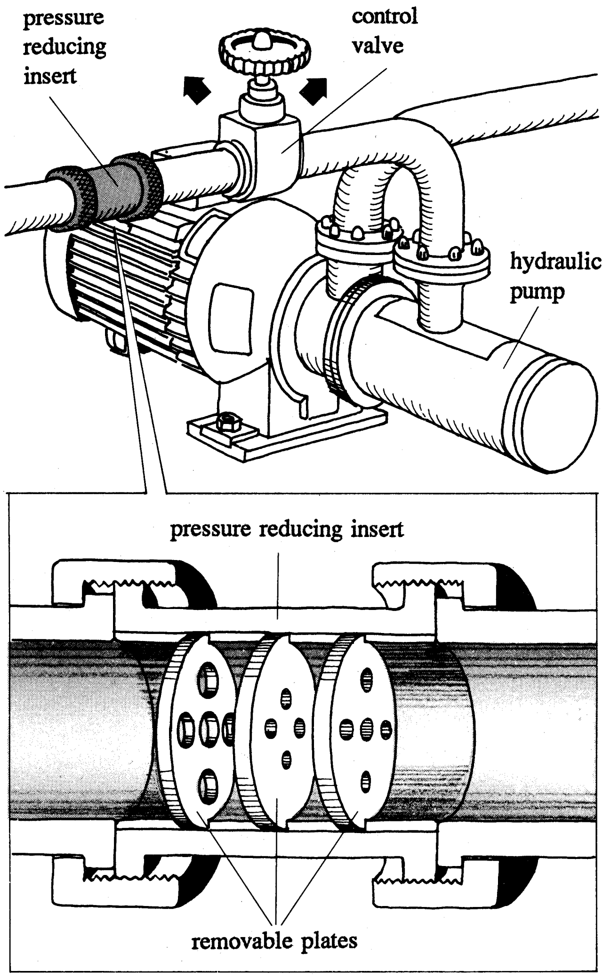


Application with pumps and valves



Example

In a hydraulic system, the full pump capacity is employed only in exceptional cases. Usually, the pressure is greatly reduced using a control valve. Cavitation can then arise, producing loud noise from the valve. The noise is conducted as solid–borne sound to connected machines and building structures.



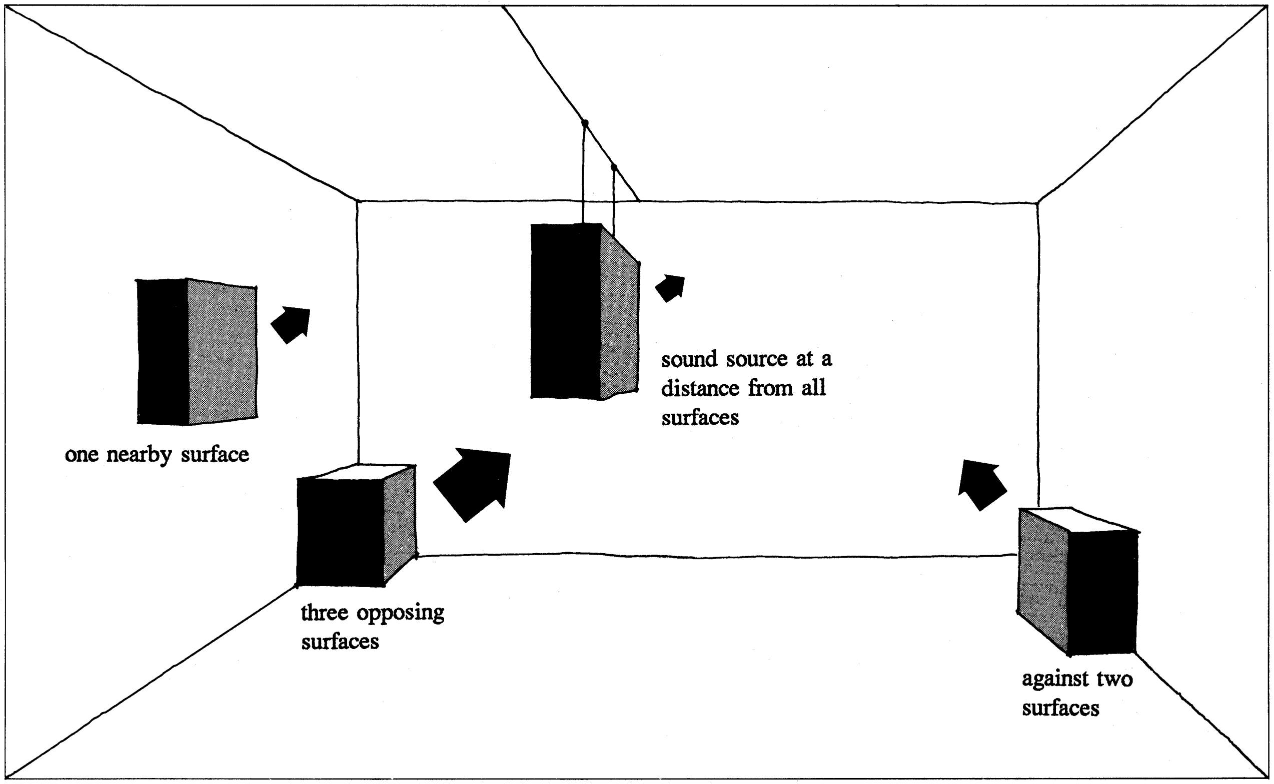
Control Measure

A pressure–reducing insert is placed in the same pipe as the control valve. The insert has removable plates with different perforations. The plates are selected so that the insert will not produce a greater pressure drop than that required to prevent cavitation.

SOUND SOURCES SHOULD NOT BE PLACED NEAR CORNERS

The closer to reflecting surfaces a sound source is placed, the greater the amount of noise it will radiate to the room. The worst placement is in corners – near three room surfaces. The best placement is away from the walls.

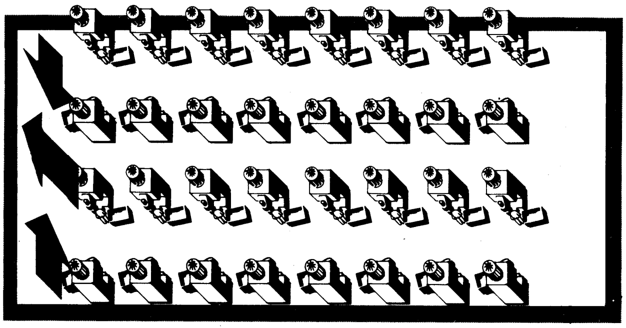
Principle



Application of machine placement

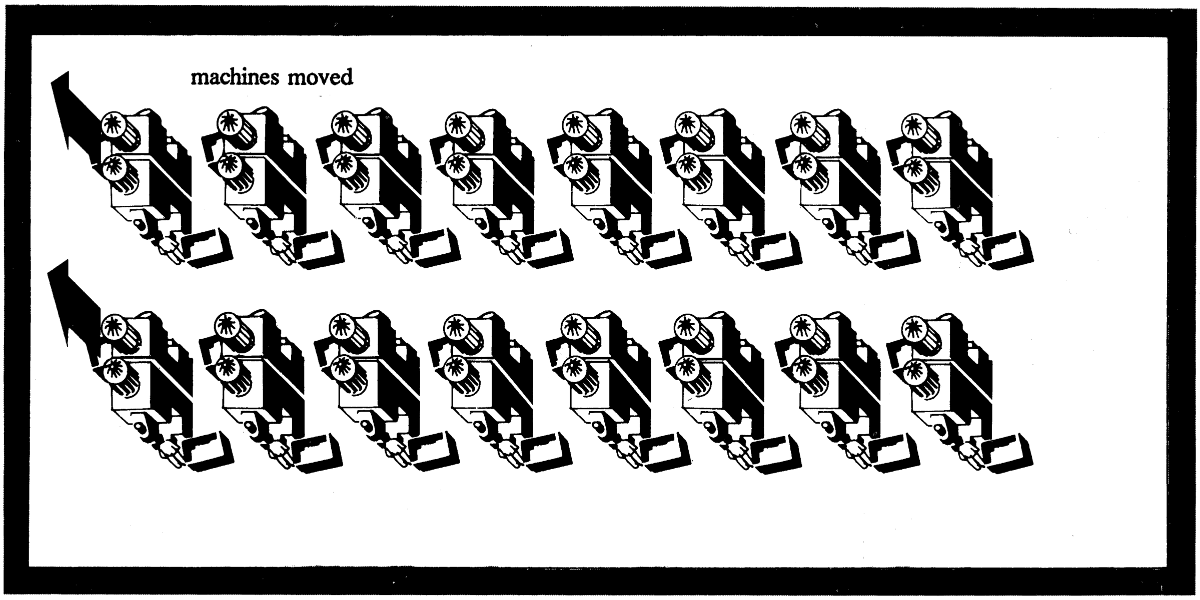
Example

In an industrial shop, machines are placed in four rows with three aisles between them. This arrangement in–creases noise from the machines in the two outermost rows.



Control Measure

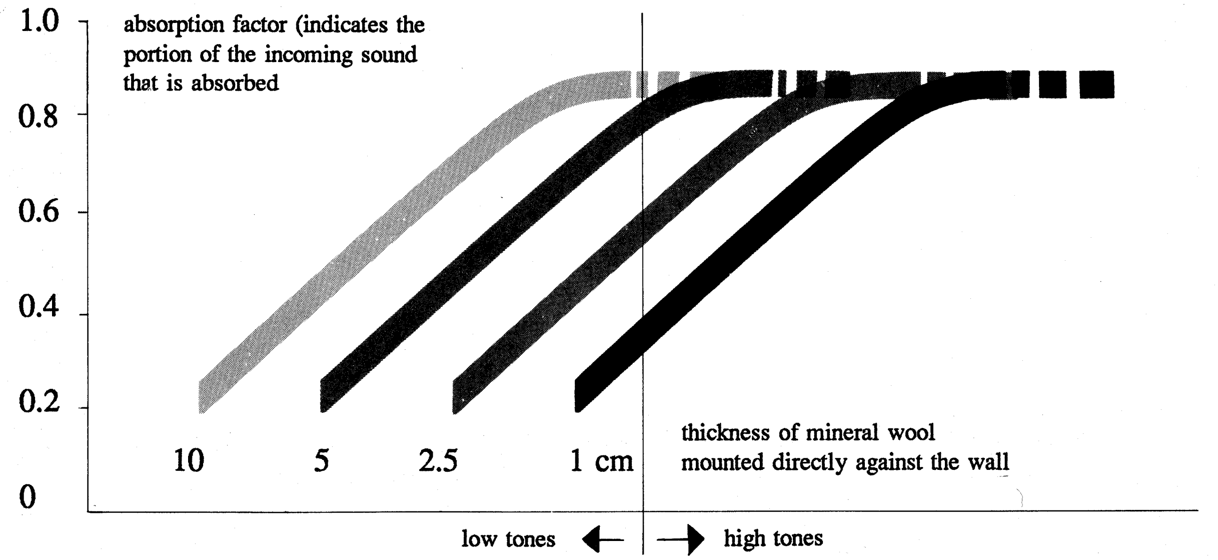
The machines are placed together, two–by–two, away from the walls, and new aisles are set up along the walls. With this new arrangement, the noise level in the installation drops.



THICK, POROUS LAYERS ABSORB BOTH HIGH AND LOW FREQUENCY SOUND

Porous material through which air can pass often makes a good sound absorber. Examples of such materials include felt, foam rubber, plastic foam, textile fibers, and a number of sintered metals and ceramic materials. If the pores are closed, the absorption is low. Thin porous absorbents handle high tones. For good absorption below 100 Hz, the thickness required may become impractical. Low frequency absorption is improved with the aid of an air gap behind the absorbing layer.

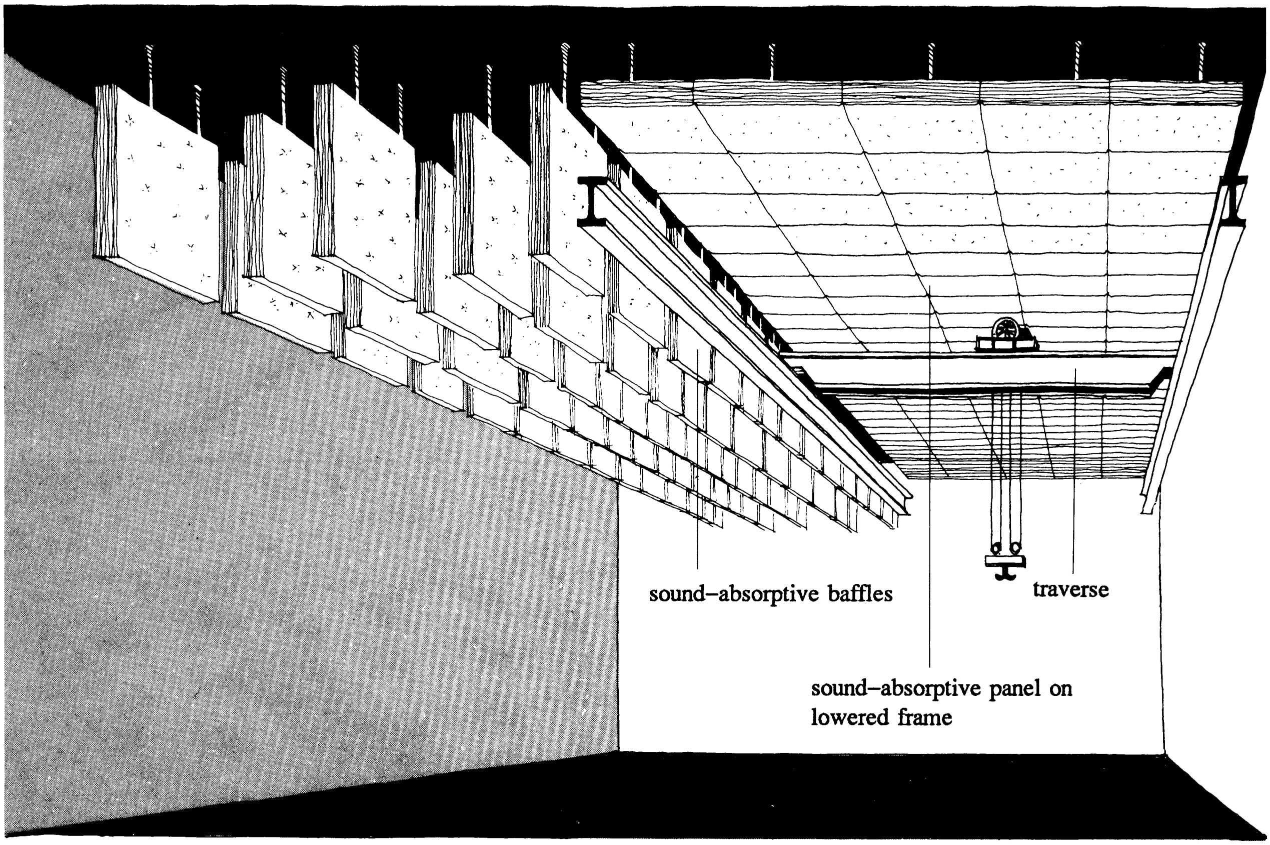
Principle



Application in large spaces

Example

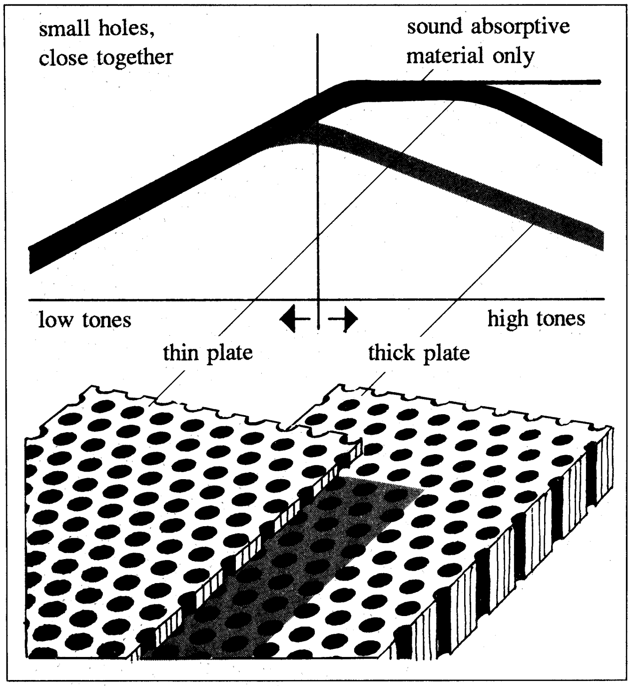
A workshop with intense low frequency noise is provided with absorbers that are effective for low tones. One part of the shop contains space for hanging sound absorptive baffles, which provide good low frequency abosrption, and are easily installed. A traverse leaves no room for baffles in the other part of the shop. Instead, horizontal sound absorptive panels are installed above the traverse, 20 cm from the ceiling, to improve the low–frequency absorption. With sound absorptive material on the walls and ceiling, the noise levels in the shop can be reduced 3 to 10 dB, except in the immediate vicinity of the noise sources.

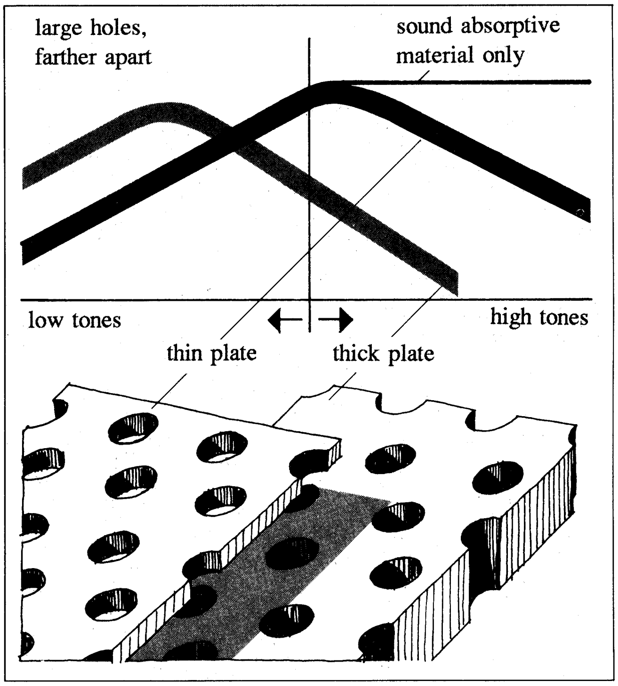


COVER LAYERS WITH LARGE PERFORATIONS MAY BE USED WITHOUT REDUCING ABSORPTION

For a variety of reasons, a covering material may be needed to protect a porous sound absorptive material. This can be done without reducing the effectiveness of the absorptive material if the covering has a sufficient number of openings. For example, a 15% open area is sufficient for a 1 mm thick sheet–metal layer. The thicker the cover layer, the larger the number of perforations that will be required. It is better to perforate with many small holes than with a smaller number of large holes.

Principle





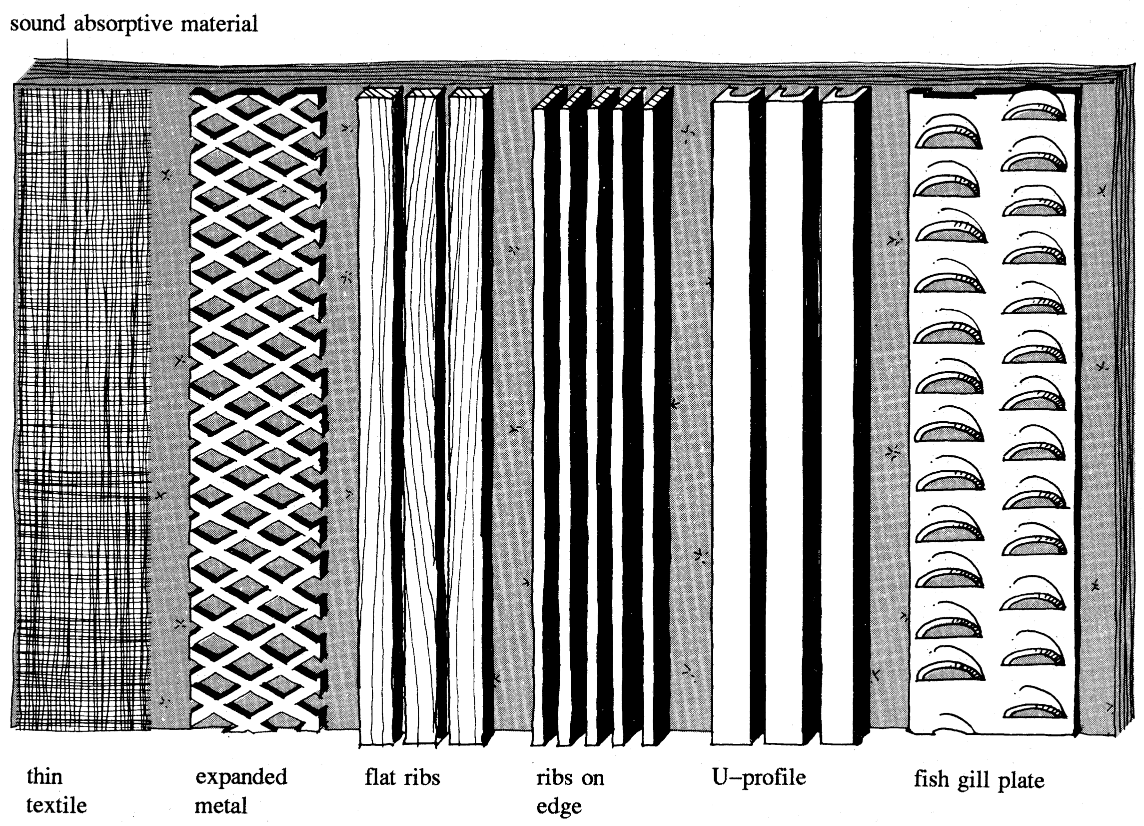
Application of wall and ceiling sound absorptive materials

Example

Sound absorptive material is required on many wall and ceiling surfaces in a building. To provide a more attractive environment, it is desirable to have many absorbers with different appearances.

Control Measure

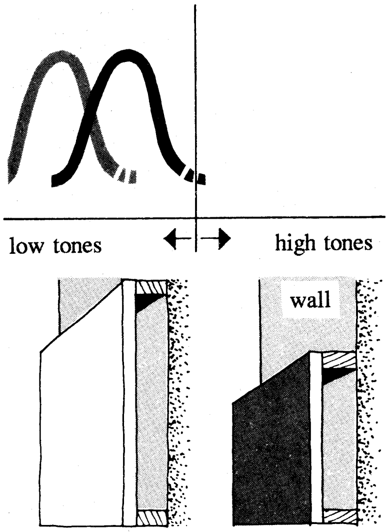
The same porous material is used on all surfaces, with varying thicknesses. Different covering materials provide the desired variation in appearance.



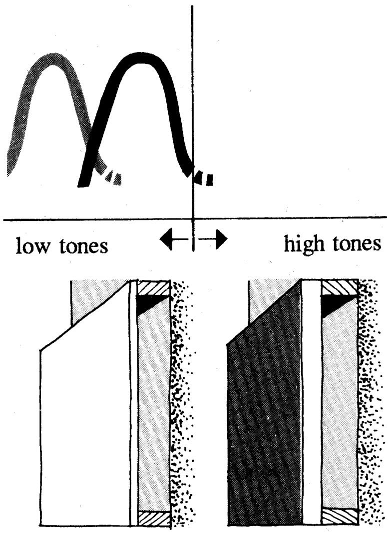
PANELS ON STUDS ABSORB LOW FREQUENCIES

Thin panels, fastened to a system of studs, absorb low frequencies. The absorption is effective over a narrow frequency range. This range is determined by the stiffness of the panels and the distance between the studs. If the panels are fastened to studs on a wall, the distance from the wall also has an effect. A panel with large internal damping absorbs over a wider frequency range.

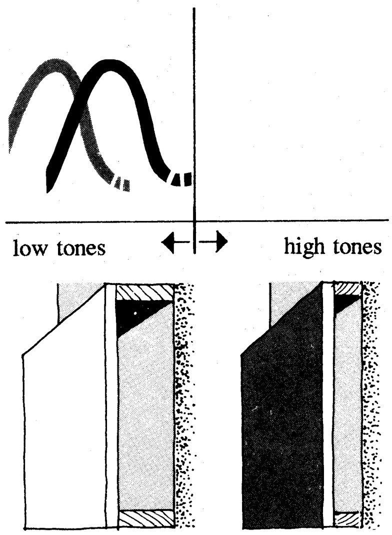
Principle



effect of distance between studs



effect of panel thickness

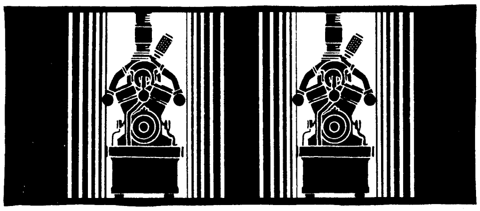


effect of distance from wall

Application in a machine room with loud low-frequency noise

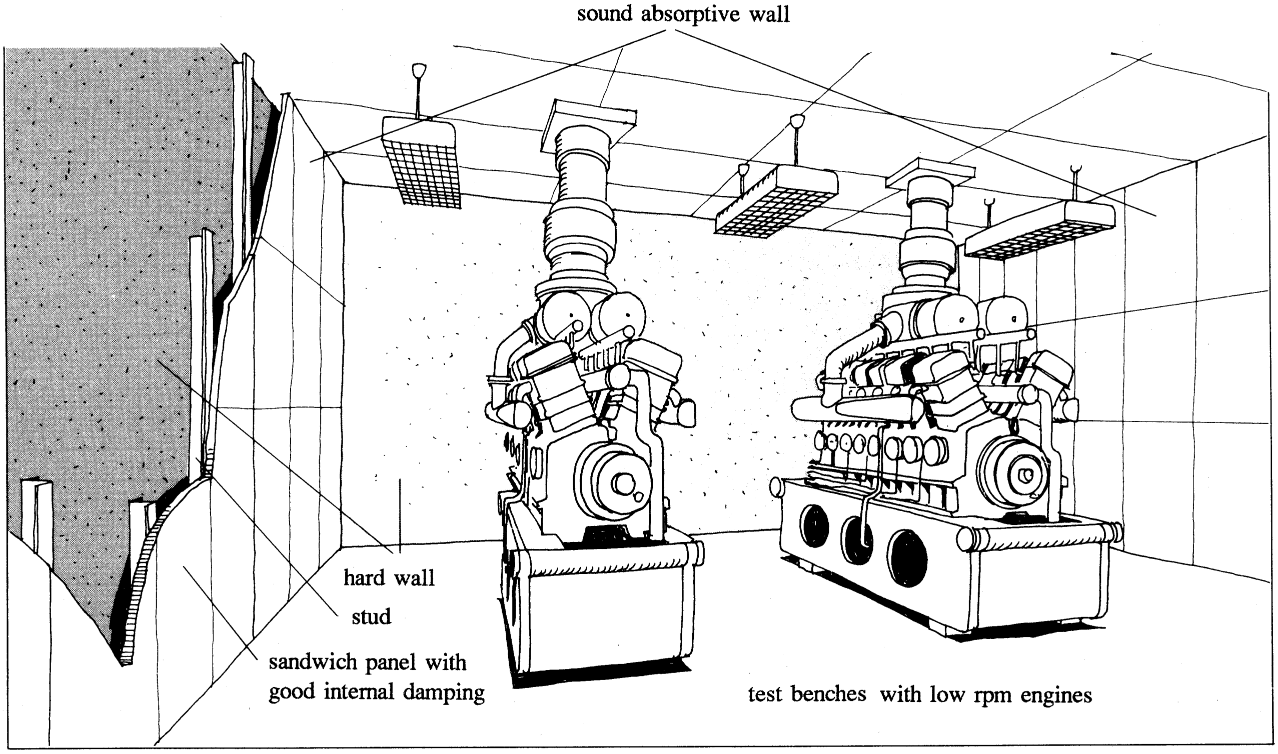
Example

Low-frequency resonance in an engine test room produced a very loud tone near the walls and in the center of the room. When the engine rotation speed was changed significantly, the tone disappeared completely.



Control Measure

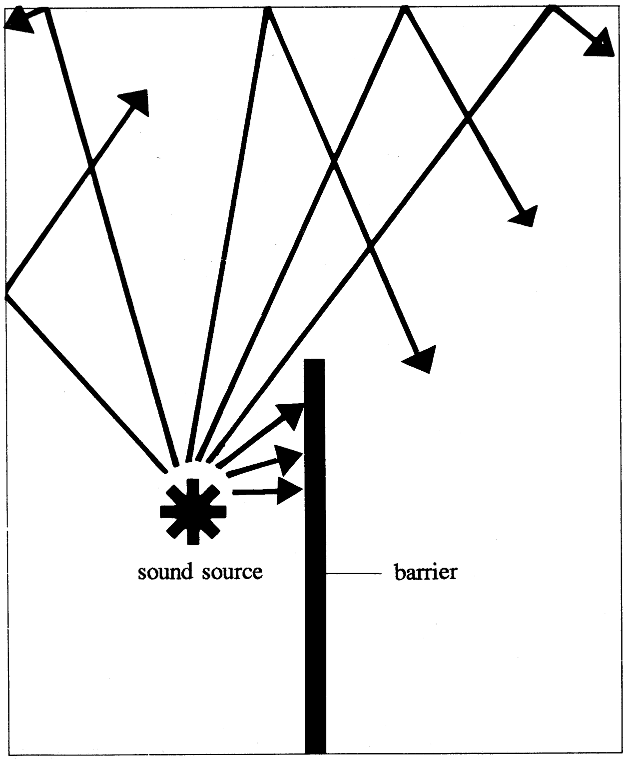
The walls were covered with panels on studs to provide the greatest absorption in the frequency range of the loudest tone. In order for the sound absorptive material to continue to function even in the case of slight variations from the normal rotation speed, a layer with good internal damping was used, which provided a wider frequency range with good absorption. As a result, the resonance and the loud tone disappeared.

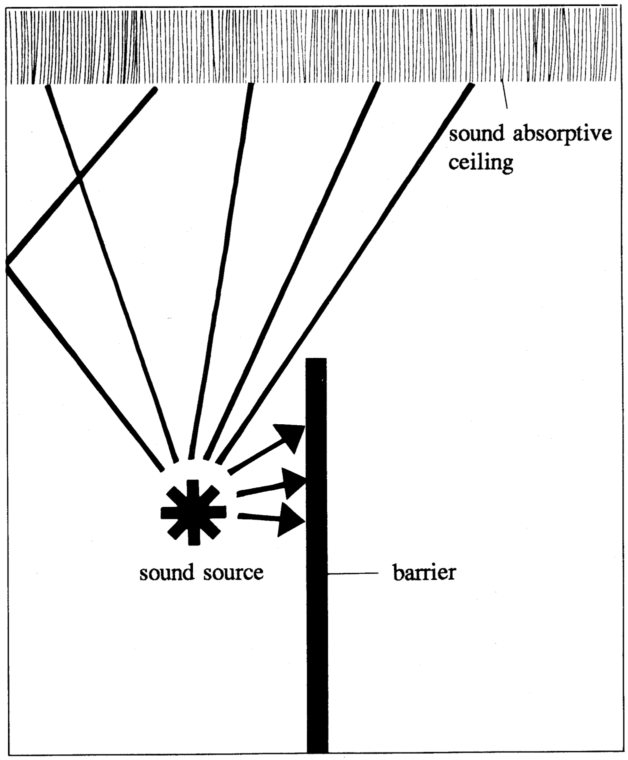


SOUND BARRIERS MAY BE COMBINED WITH SOUND ABSORPTIVE CEILINGS

High frequency noise can be reduced by using a barrier. The barrier is more effective the taller it is and the closer it is placed to the source. The effect of a barrier is considerably reduced if the ceiling is not covered with a sound absorptive material.

Principle

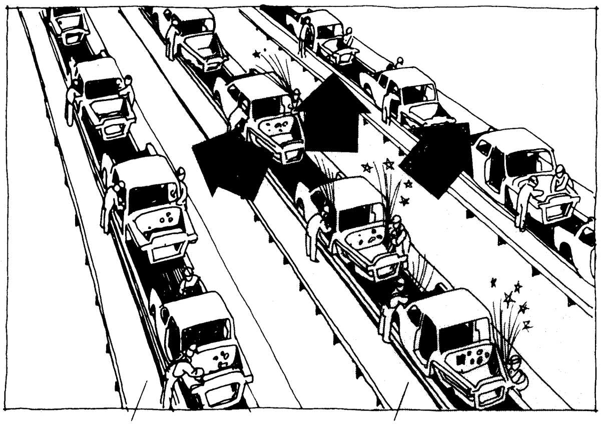




Application on a factory floor

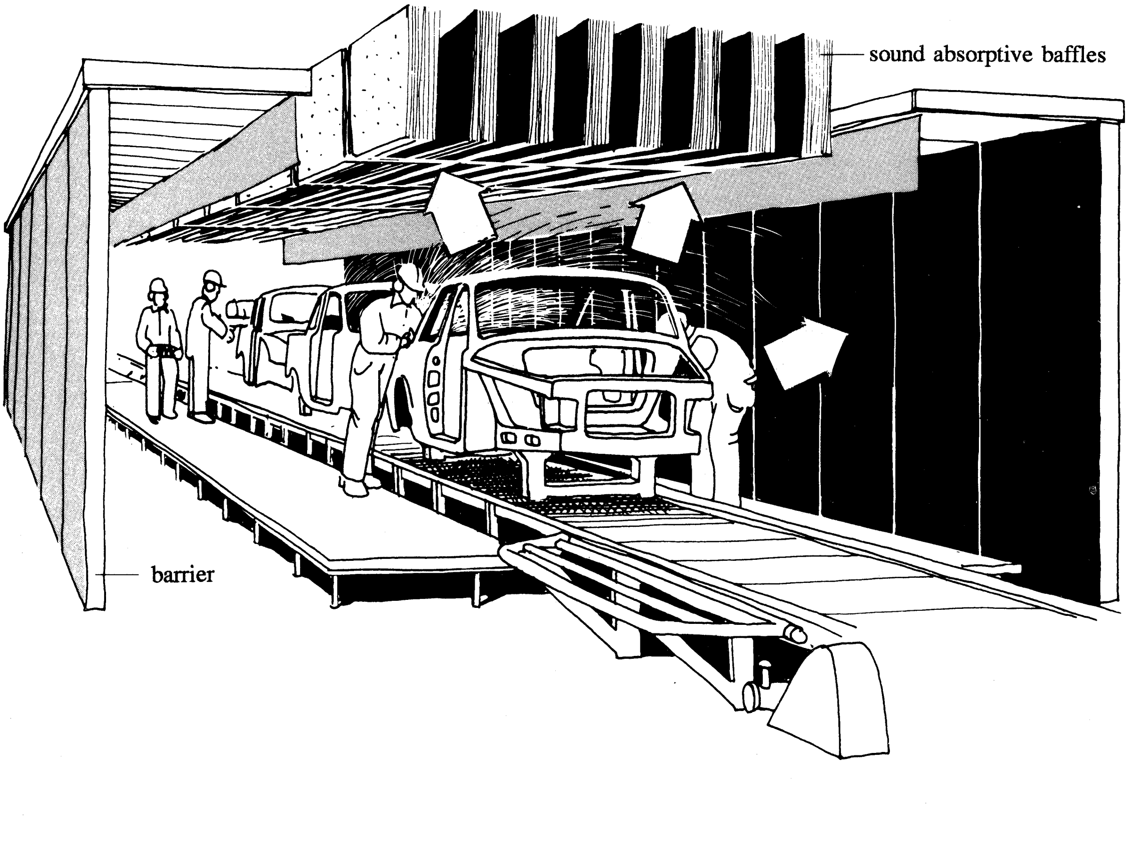
Example

In an auto plant with several assembly lines, the work on one line is noisier than the others. Grinding work on the bodies produces a shrieking, high frequency sound, disturbing everyone in the plant.



Control Measure

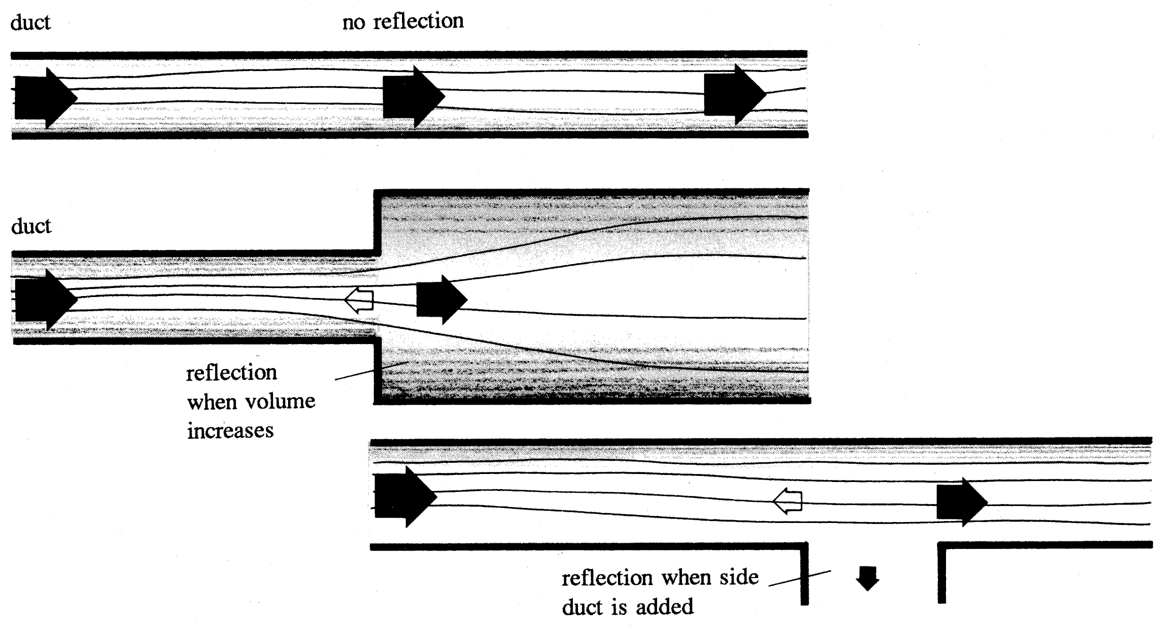
The other lines are protected from the grinding noise by means of barriers on both sides of the line and sound absorptive baffles suspended above the open area.



ALL DUCT CHANGES REDUCE SOUND TRANSMISSION

With every change in the pathway, some sound energy is reflected back. In a duct, this applies to all changes in cross–section due to bends and branches, as well as to changes in volume, shape, and wall material. Reflections are useful for sound damping. A muffler that reflects sound energy back to the source is a reactive muffler. One that converts sound into heat is a dissipative muffler.

Principle



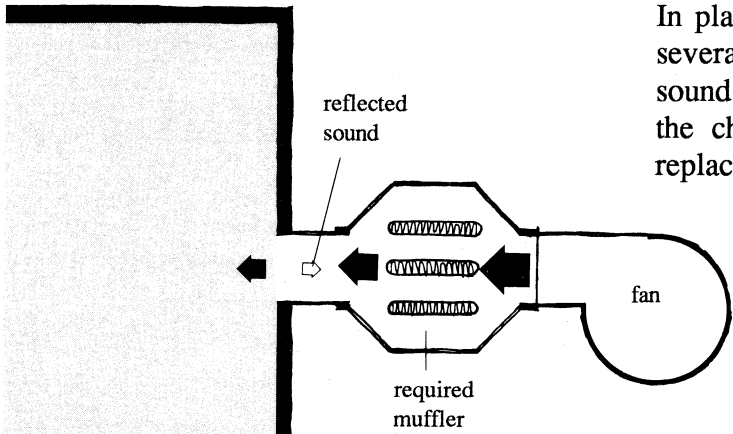
Application to a ventilating system

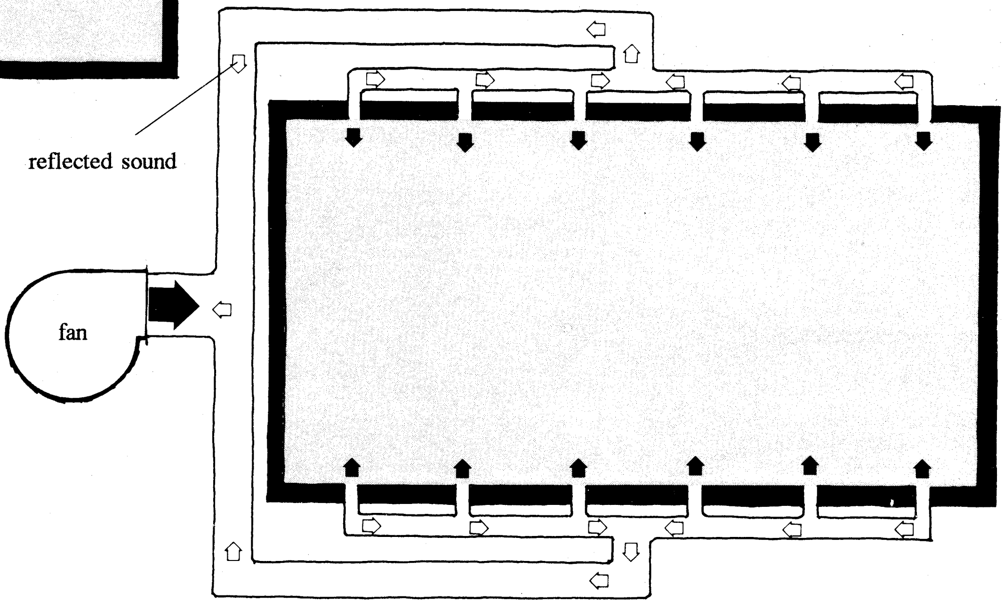
Example

An area is to be provided with mechanical ventilation. There is sufficient space for the fan to be installed, but not for a required muffler.

Control Measure

In place of a single inlet into the room, several smaller inlets are installed. The sound reflection that takes place with all the changes in area and at each bend replaces the muffler.

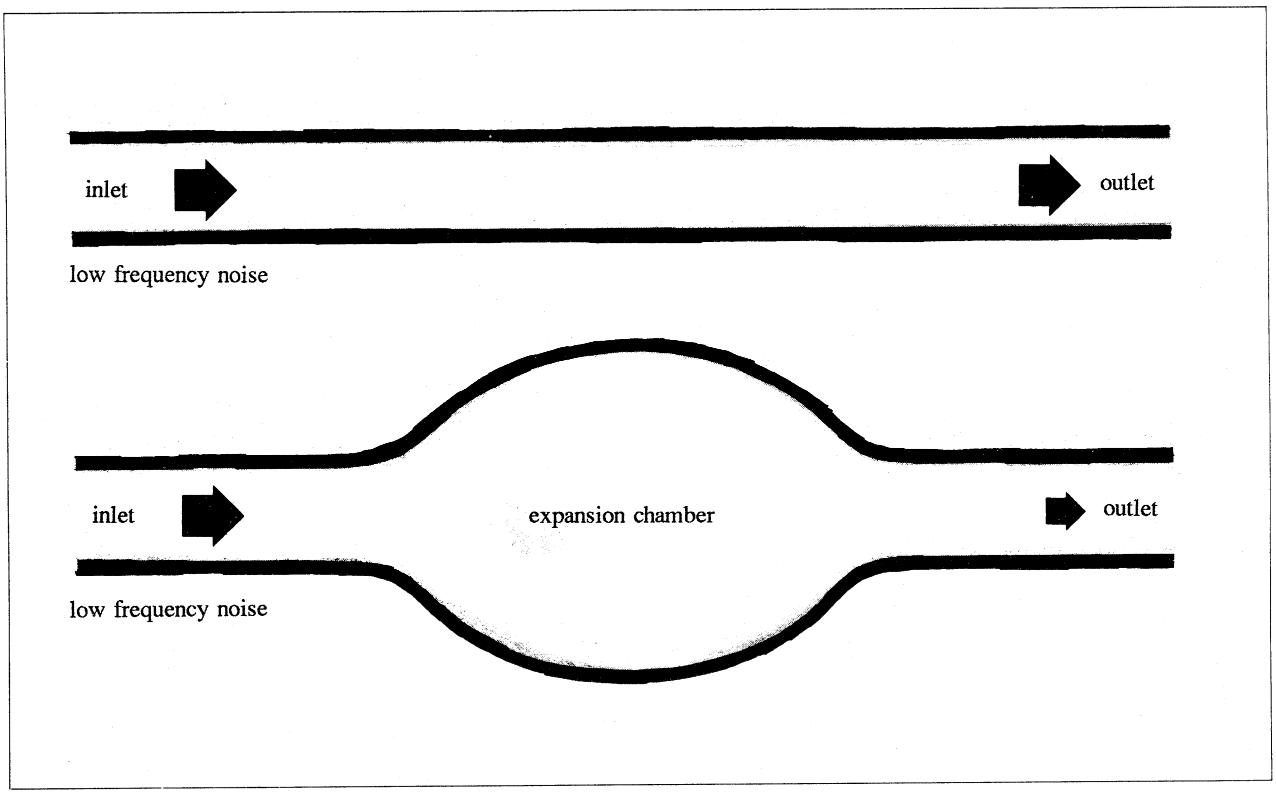




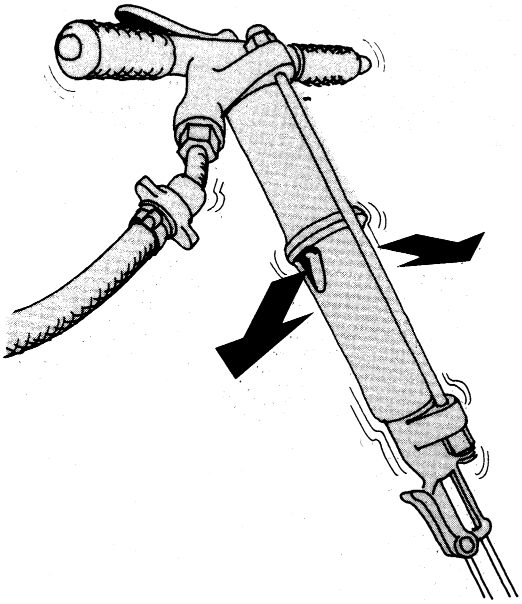
EXPANSION CHAMBERS ARE USEFUL FOR REDUCING LOW–FREQUENCY NOISE

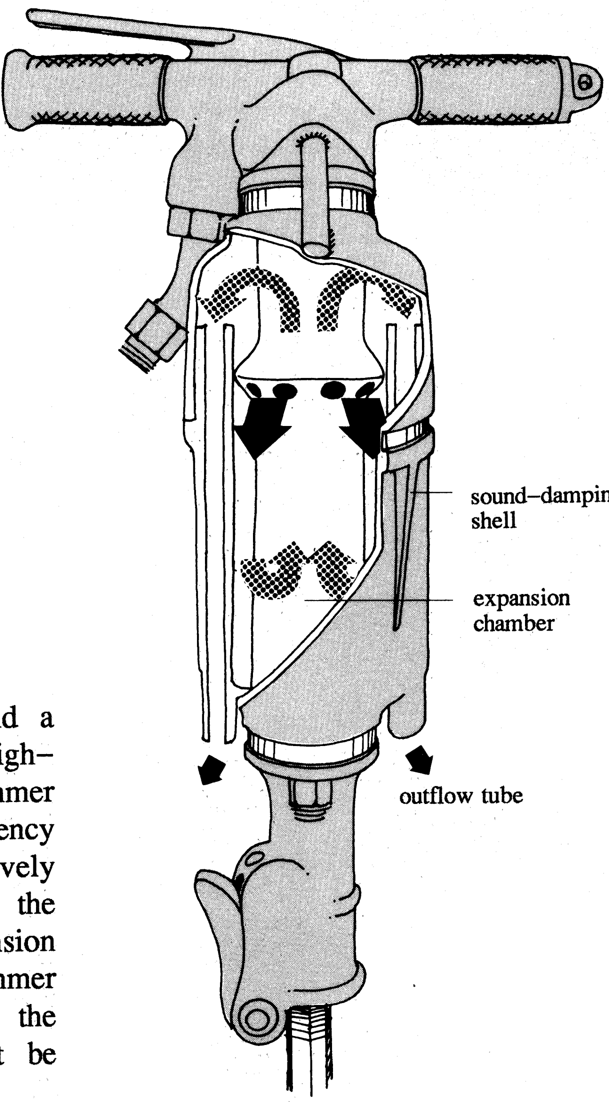
If a duct is provided with an expanded section or chamber, the low–frequency pressure variations in the duct are reduced. The lower the frequency which must be reduced, the greater the volume required in the chamber.

Principle



Application to a jack hammer





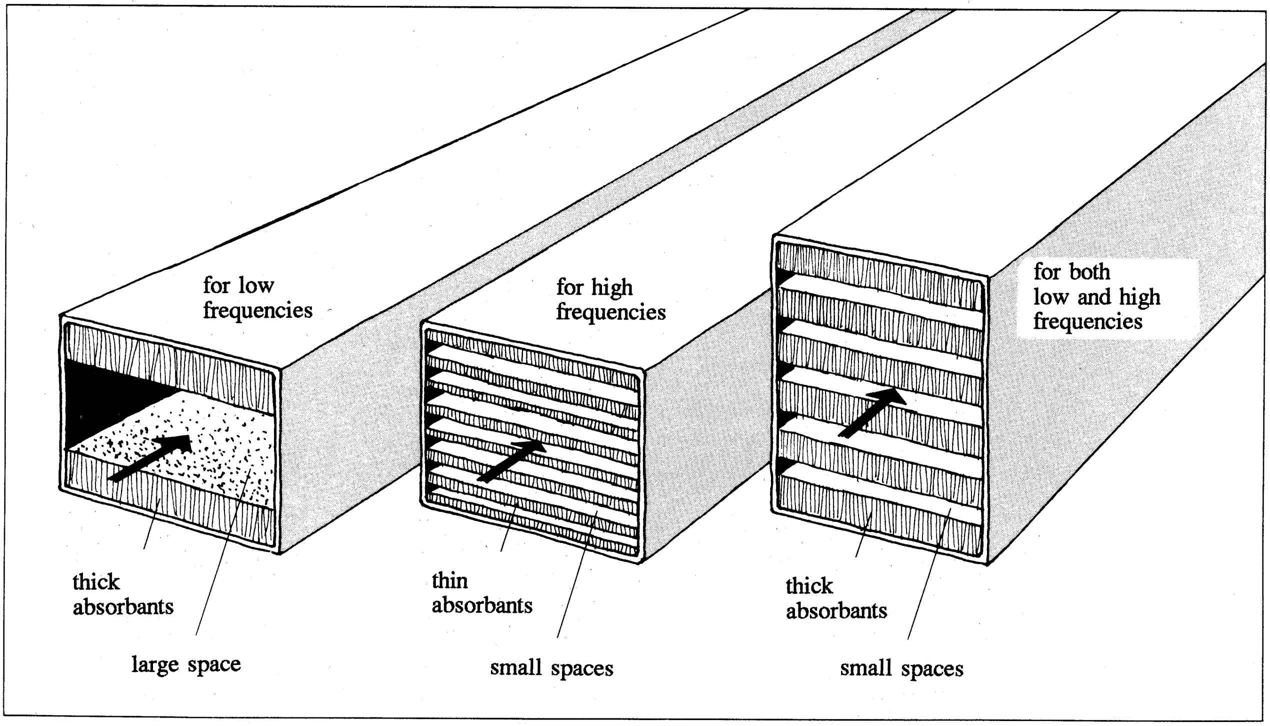
Example

Using a jacket over the hammer and a tubular outlet in the jacket, the high–frequency noise radiated by a jack hammer can be partially shielded. The low–frequency noise in the exhaust air is effectively reduced. The enlarged area between the barrel and jacket functions as an expansion chamber. Because the impact of the hammer on the work material creates noise, the operation of a jack hammer cannot be completely quieted.

DISSIPATIVE MUFFLERS ARE EFFECTIVE OVER A BROAD RANGE OF FREQUENCIES

The simplest form of a dissipative muffler is a duct with sound–absorptive material on the walls. The thicker the material, the lower the frequency that can be absorbed. For higher frequencies, the space between the absorbing walls must be made smaller. A large duct must therefore be subdivided into many smaller ones.

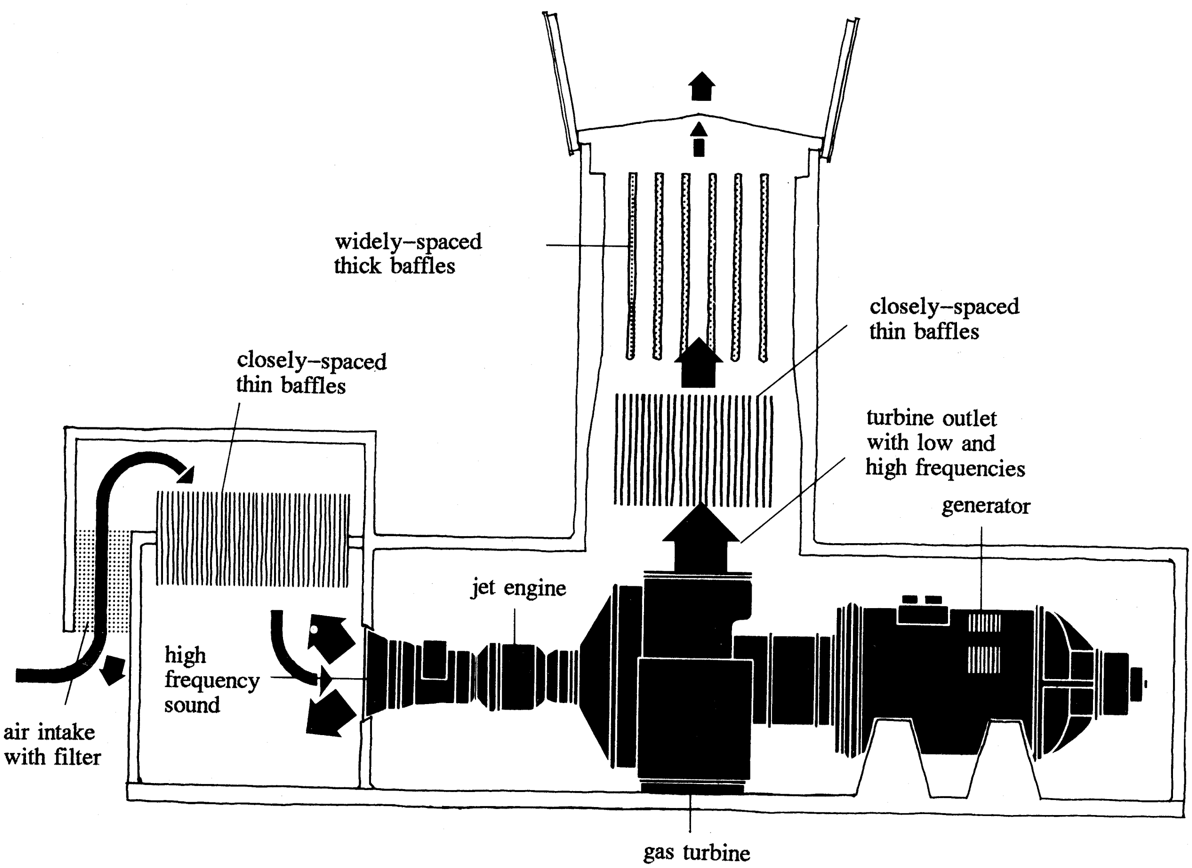
Principle



Application to a gas turbine power station

Example

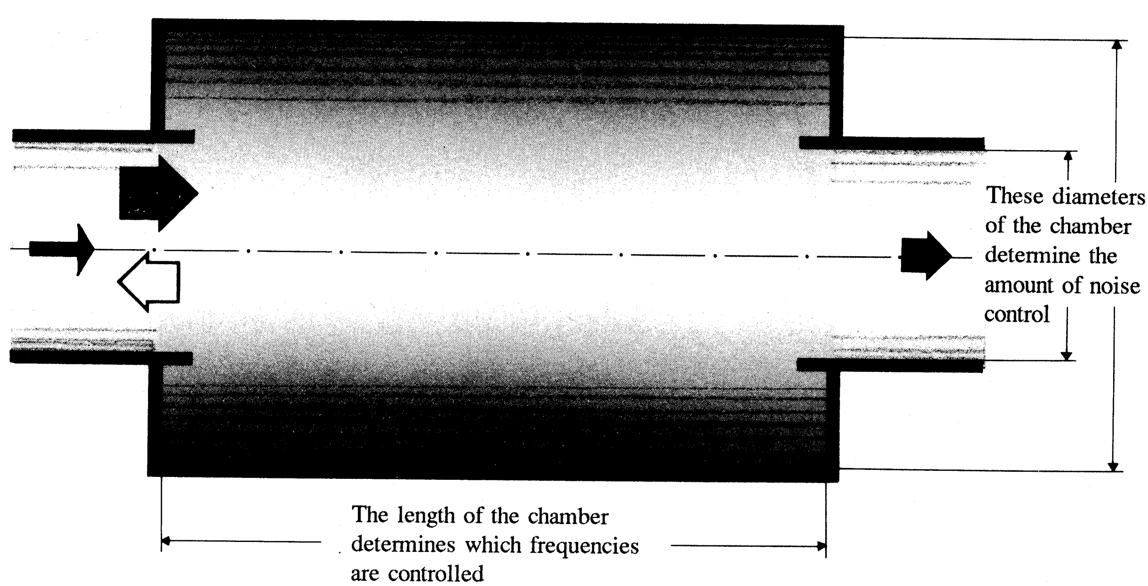
A common form of back–up power station is one driven by a jet aircraft enbine. Noise reductions up to 70 dB are frequencly required. If noise in a very wide frequency range is to be reduced, it is generally necessary to employ dissipative mufflers with thick and thin baffles of perforated sheet metal filled with mineral wool.



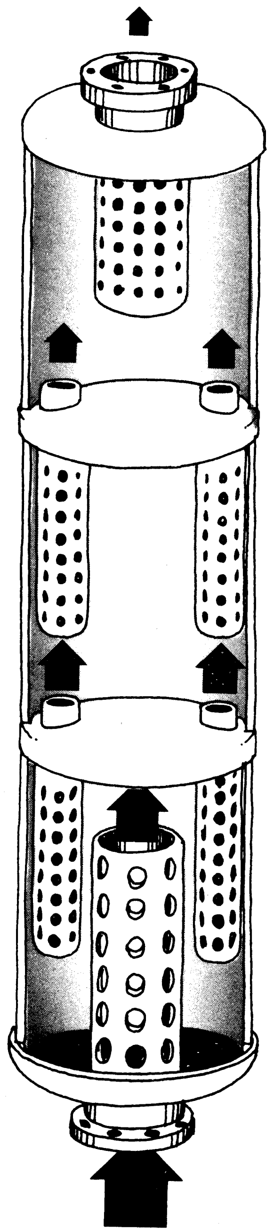
REACTIVE MUFFLERS ARE EFFECTIVE IN NARROW FREQUENCY RANGES

When noise is present in a limited frequency range, a reactive muffler may take up the least space. These are generally used at low frequencies. A frequency range can be covered by using configurations with several tubes and chambers. One example of a simple element is shown below.

Principle



Application for motor exhaust



Example

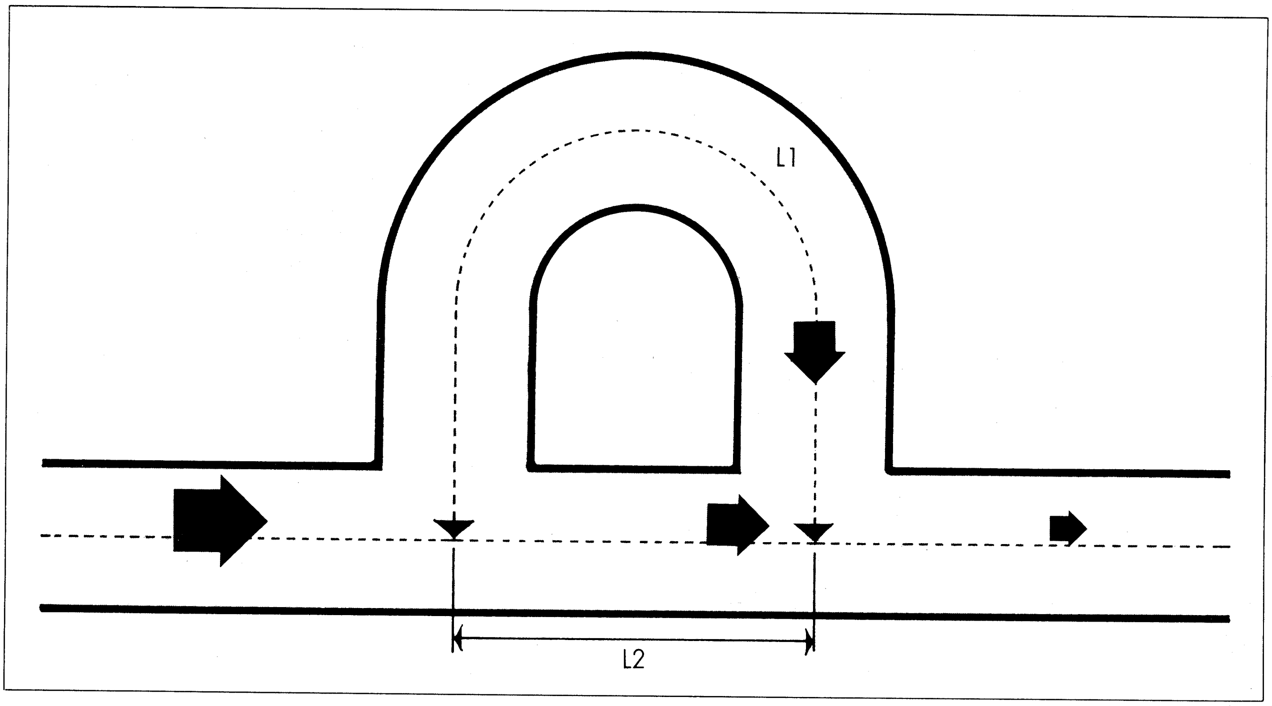
The type of muffler shown here is used primarily in large piston engines.

reactive muffler with three stages

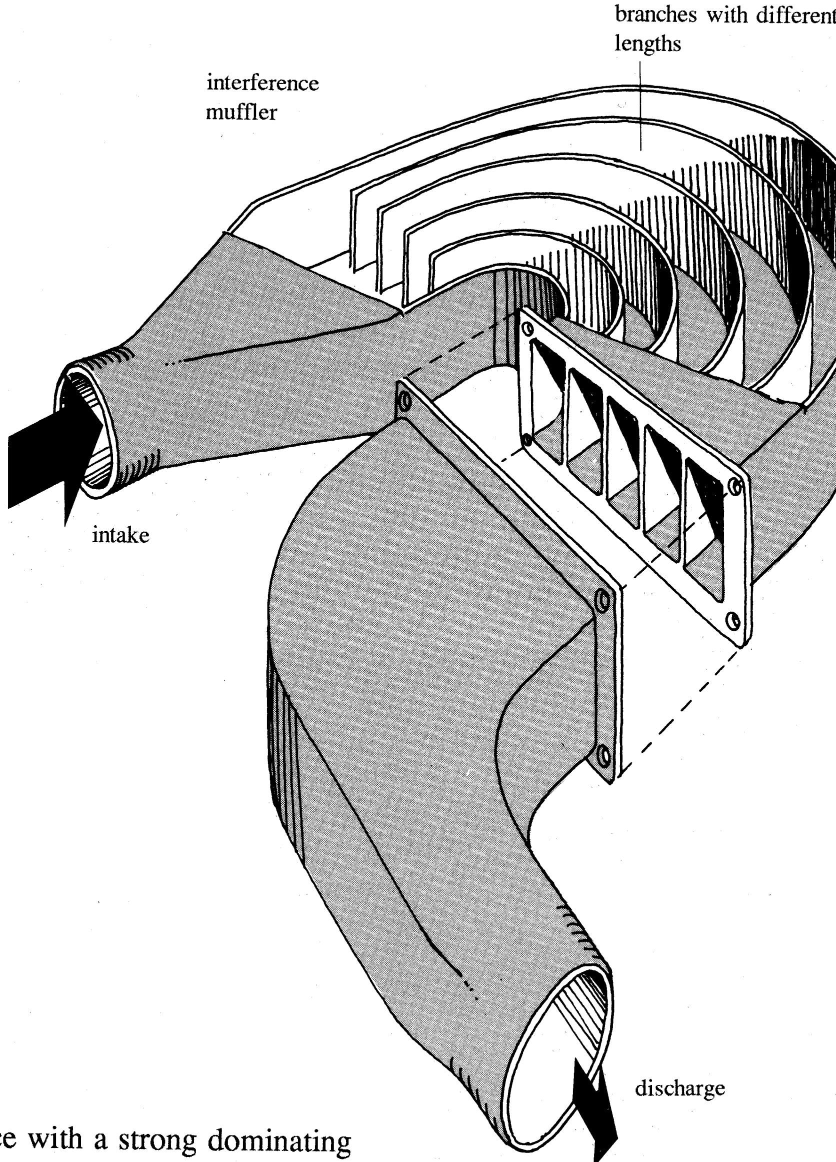
PURE TONES CAN BE ELIMINATED BY CANCELLING SOUND

When the sound contains only a single tone, or several tones within a narrow frequency range, the tone(s) can be wholly or partially eliminated in an interference muffler. This type of muffler utilizes one or more side branches through which the sound travels a longer path, so that it interferes with the sound traveling straight through the duct. In the simplest configuration, as seen in the figure below, the path difference, L1 – L2, determines the frequency for which the muffler is effective. The time–delayed sound cancels the direct sound.

Principle



Application for noise with a strong pure tone



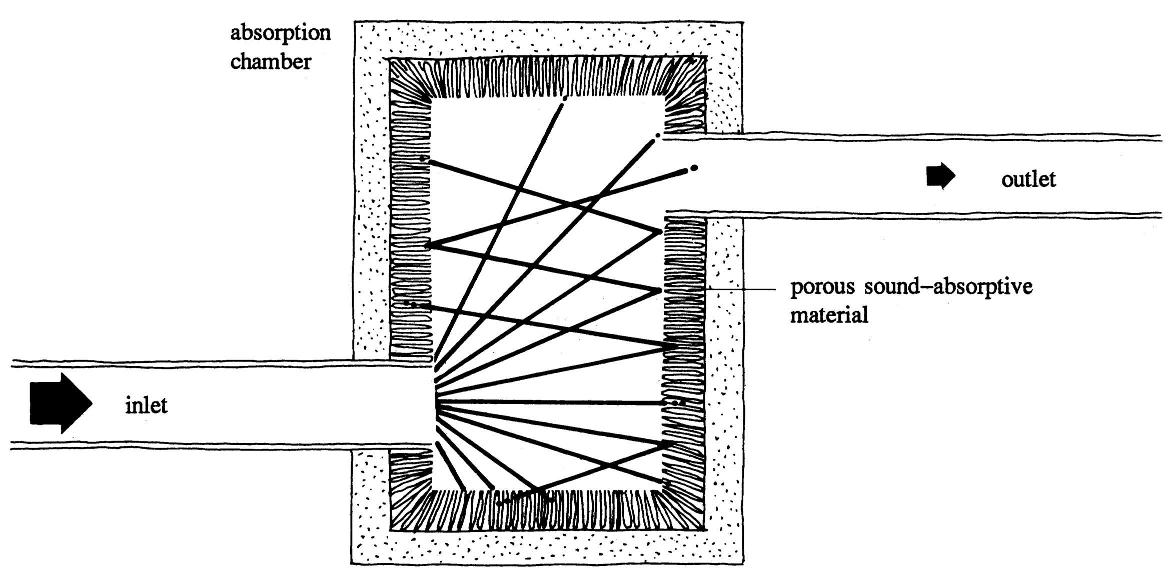
Example

A silencer for a sound source with a strong dominating tone. When the tone's frequency or the temperature of the gas in the duct are not steady, the frequency range over which the muffler is effective may be broadened due to variations in the path length differences between side branches. In this case, the reduction for a single pure tone is somewhat lower. Interference mufflers are most useful for motors which operate at a constant speed.

UNUSED SPACES CAN BE BE ABSORPTION CHAMBERS

The absorption chamber is a simple muffler. One section of the muffler consists of a room whose walls are covered with sound–absorptive material. When sound is reflected by the chamber walls, sound energy is absorbed. To prevent the passage of high–frequencies, the inlet and the outlet of the chamber should not be located opposite one another. The greater the chamber volume and the thicker the absorptive material used, the lower the frequency at which the muffler is effective.

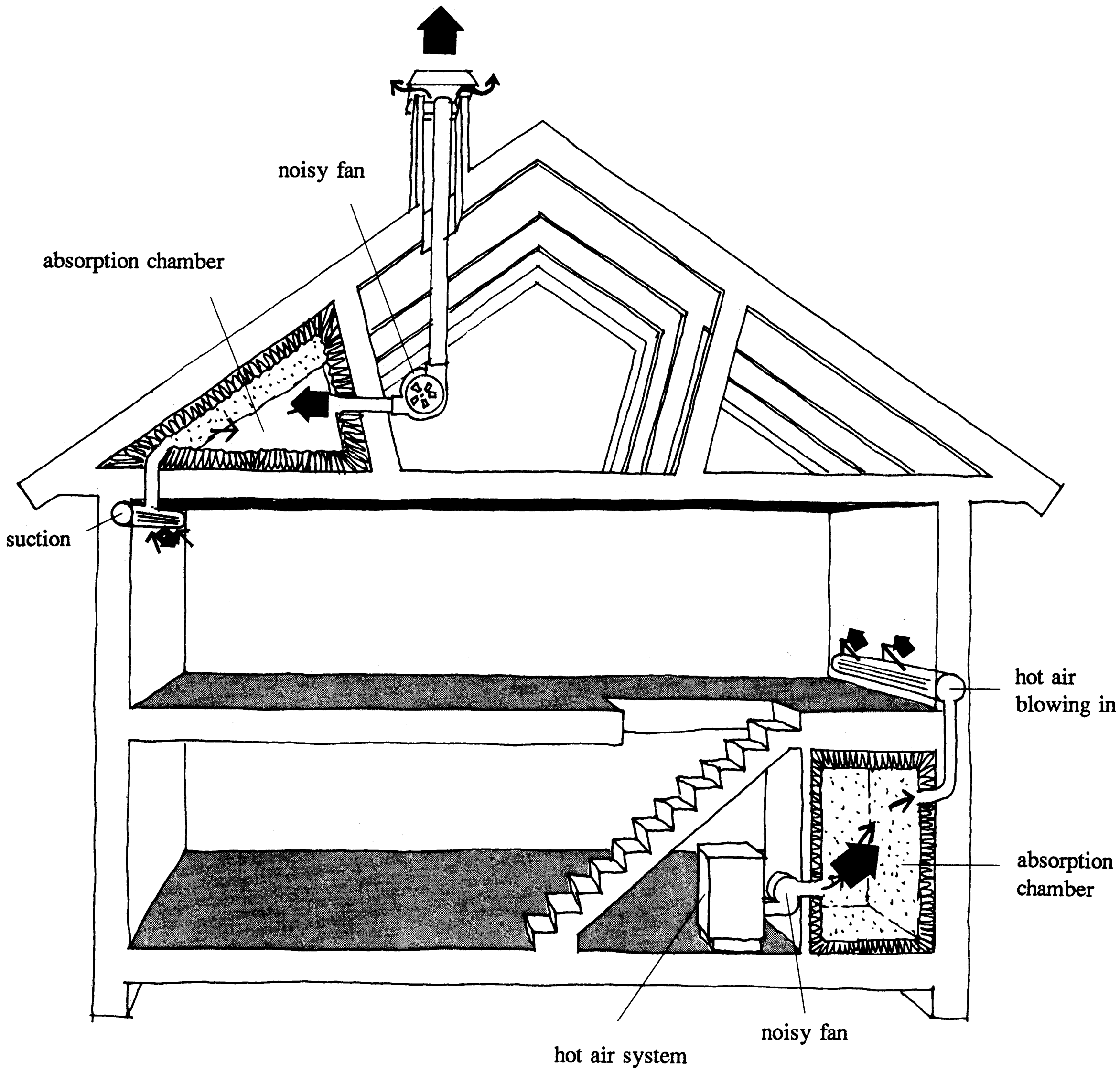
Principle



Application to a ventilation system.

Example

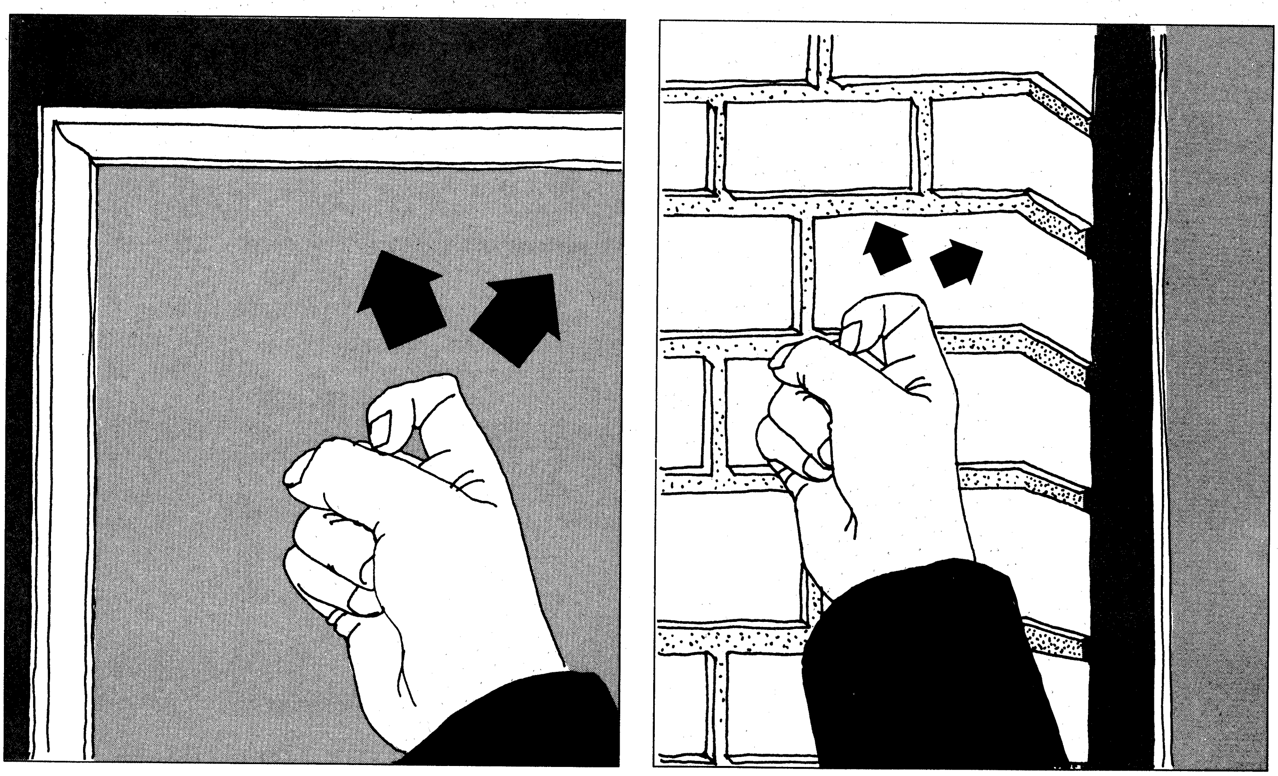
The shape of the absorption chamber is of little significance. Unused spaces can be simply converted to absorption chambers.



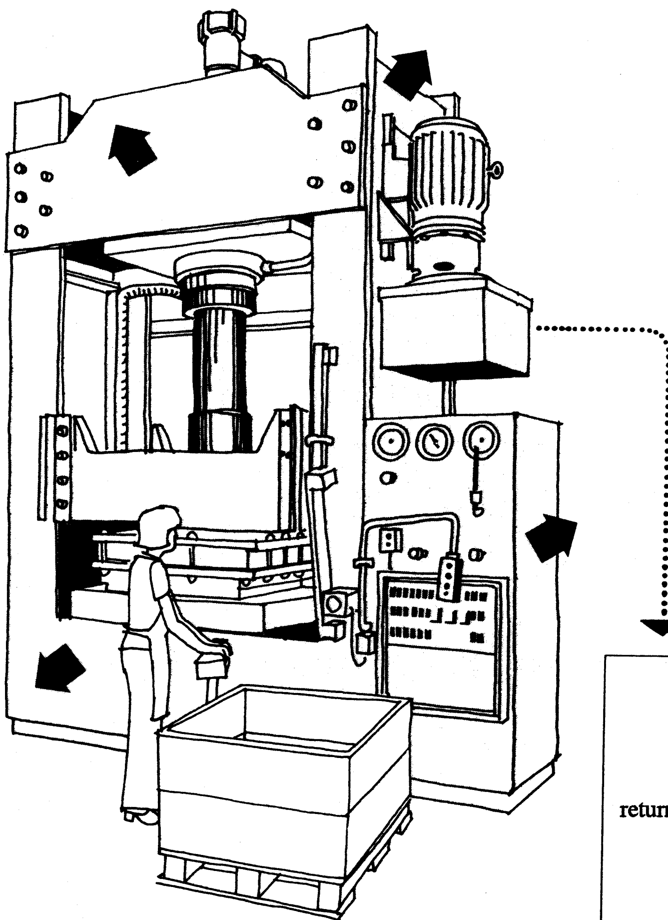
MACHINES WHICH VIBRATE SHOULD BE MOUNTED ON HEAVY, RIGID BASES

Knocking on a thin door produces more sound than knocking on a thick wall. For the same reason, noise sources should be mounted on heavy or rigid bases.

Principle

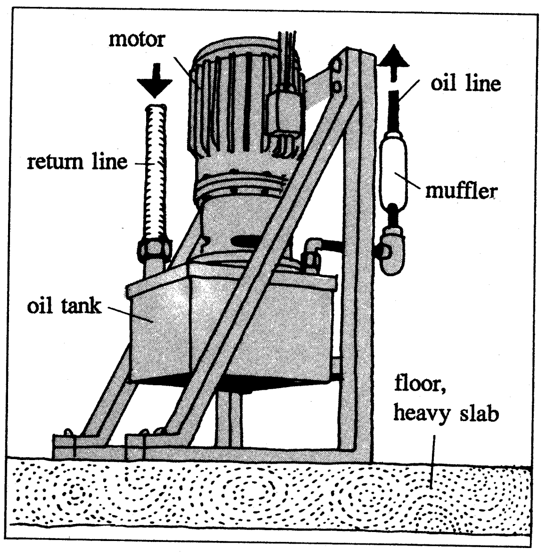


Application of different ways of machine mounting



Example

A motor–driven oil pump is placed on the side of the frame of a hydraulic press. Vibrations are transmitted to all parts of the frame, which convert the solid borne sound to loud airborne sound.



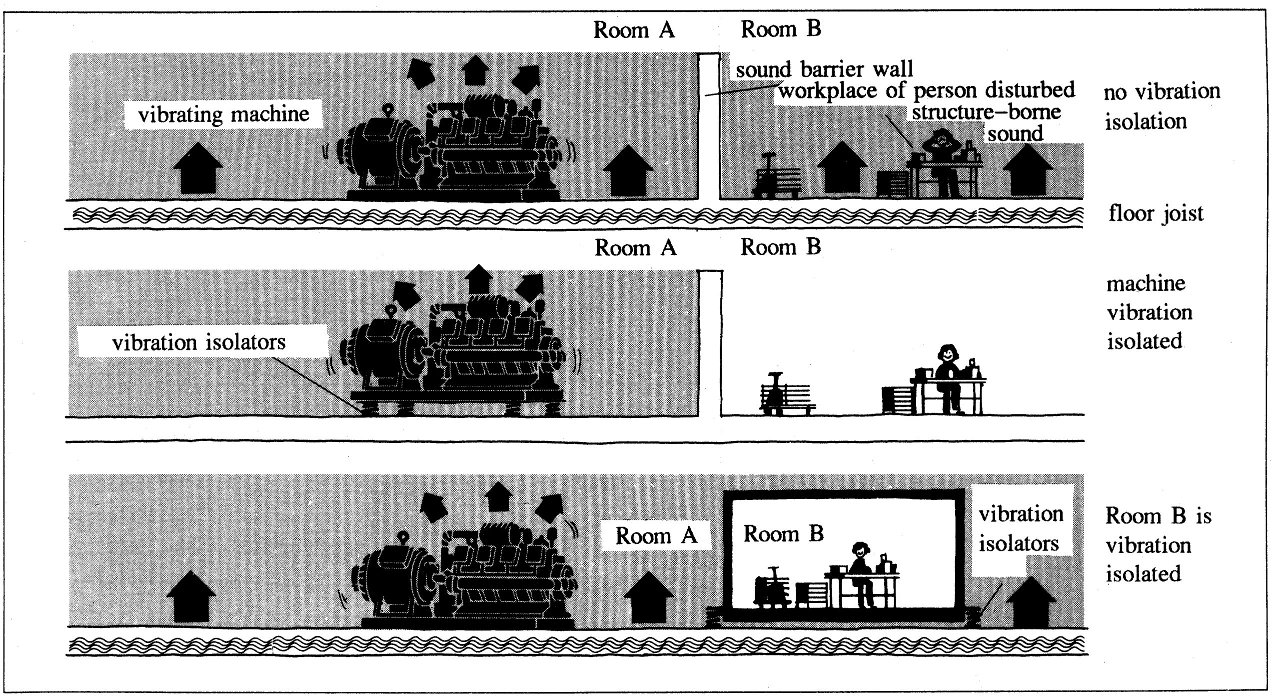
Control Measure

The oil system is removed from the press and installed in a rigid frame directly bolted to the thick massive floor. Sound transmission in the oil line is controlled with a muffler. The sound level at the operator's position drops significantly.

MACHINES CAN BE VIBRATION ISOLATED WITH FLEXIBLE ELEMENTS

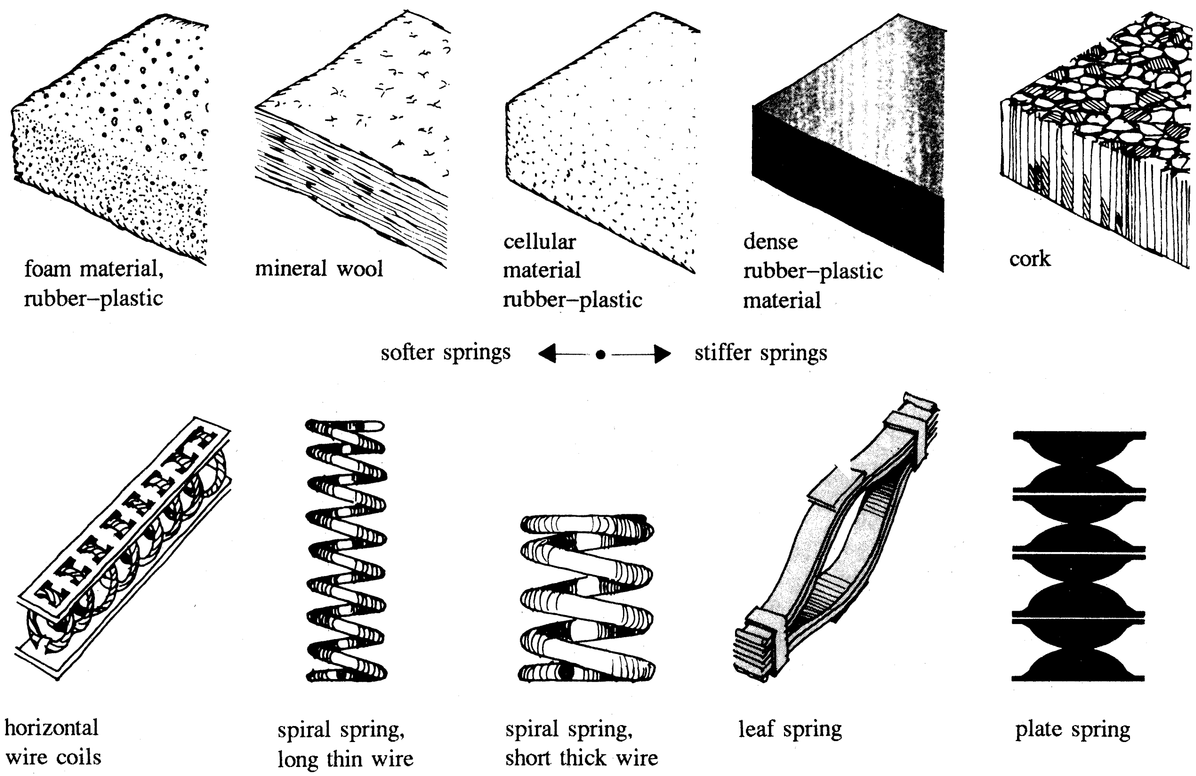
With elastic elements inserted between the base of a machine and the floor, the transmission of vibrations as solid–borne sound can be effectively reduced. The solid–borne sound transmitted from a machine room to other parts of the same building can be reduced either by vibration isolating the machines or by vibration isolating the room receiving the solid–borne sound from the building structure.

Principle



Example

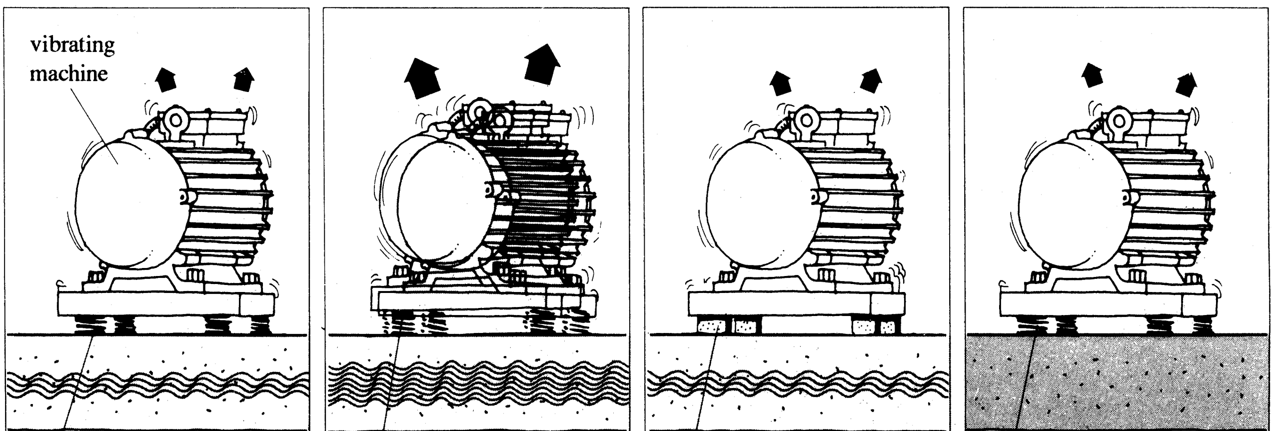
Vibration isolators are elastic units made of various materials and in various shapes. In many cases, springs with internal energy losses are useful. Of the natural materials, cork is best, followed by natural rubber. With synthetic rubber and special plastics, springs with very high internal damping can be obtained. A vast assortment of ready–to–mount vibration isolators is available.



IMPROPERLY SELECTED ISOLATORS CAN INCREASE VIBRATIONS

A machine mounted on flexible elements, or isolators, has a "fundamental frequency." If the foundation is very heavy, this frequency is determined by the combined weithts of the machine and its base, and the stiffness of the isolator. The lighter the machine and the stiffer the isolator, the higher is the fundamental frequency. Vibrations at lower frequencies than the fundamental are not blocked. Vibrations at or close to the fundamental are greatly intensified. The machine may even break away from its mounting. This situation can be avoided by using elements with good internal damping.

Principle



springs without internal damping	springs without internal damping	springs with good internal damping	springs without internal damping
vibration frequencies lower than fundamental frequency	vibration frequency close to fundamental frequency	vibration frequency close to fundamental frequency	vibration frequency higher than funda–menal frequency
no isolation	dangerous reinforce–ment of vibrations	no isolation	good isolation

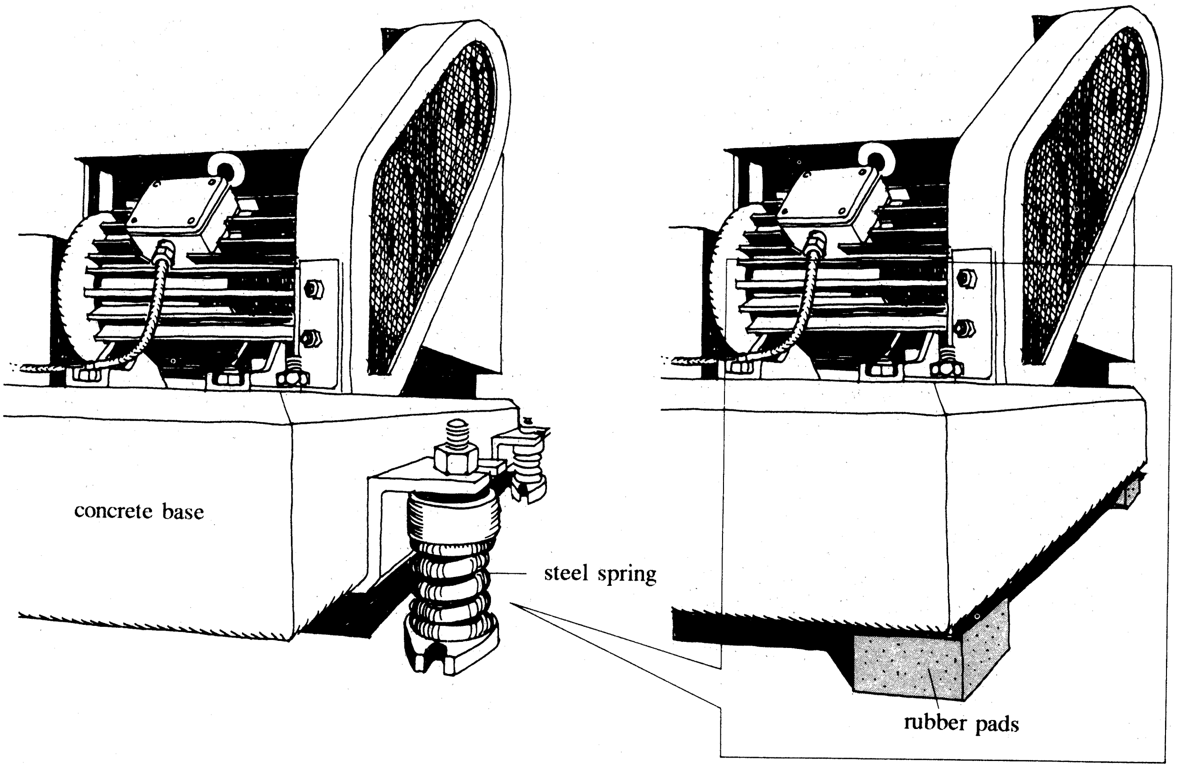
Application to a machine that often starts and stops

Example

Two fans are used in the same building. Both are vibration isolated with steel springs which have very poor internal damping. The isolation functions well for both fans during steady operation, but one of the fans is started and stopped frequently. When this happens, the vibration frequency corresponds, for a short time, with the fundamental frequency — which produces a serious disturbance.

Control Measure

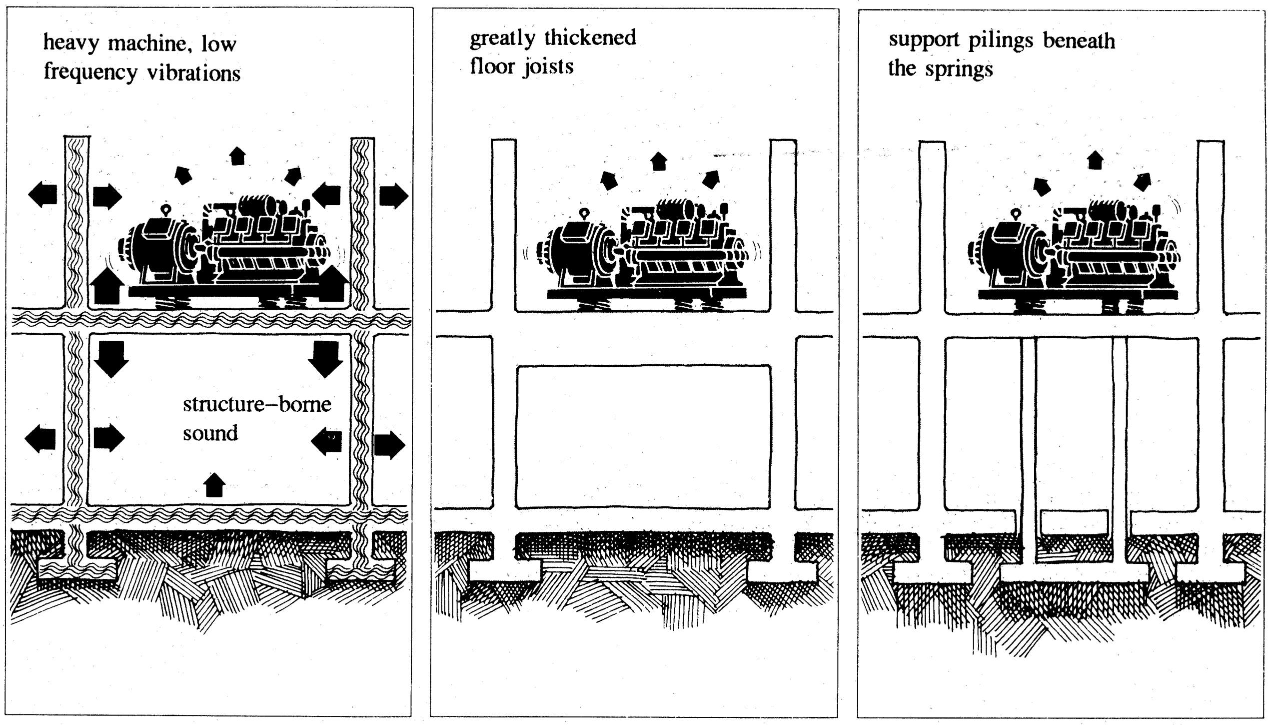
On the fan with irregular operation, the steel springs are exchanged for rubber pads with good internal damping. The isolation is somewhat less, but the disturbance from starting and stopping disappears.



HEAVY MACHINES PRODUCING LOW FREQUENCY VIBRATIONS REQUIRE A RIGID FLOOR

Floor joists have a large number of resonances which make it difficult to vibration isolate a machine with elastic materials. A heavy machine producing low frequency vibrations is difficult to isolate unless the floor is very rigid. As shown below, an extra heavy (stiff) or pile–reinforced floor may be necessary.

Principle



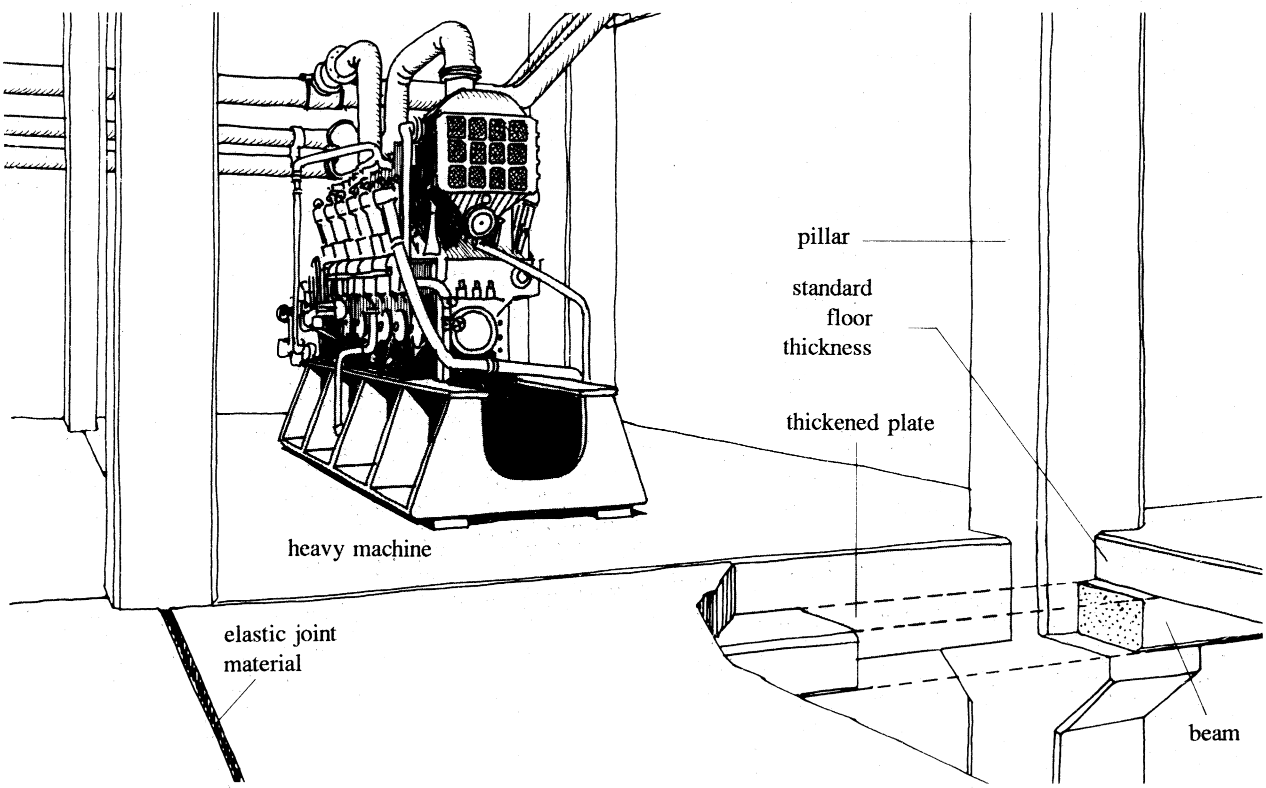
Application to heavy machines in multi-story buildings

Example

A company is planning a building where a need for freedom from vibration and noise is great. It should also be possible to remove and interchange the machines.

Control Measure

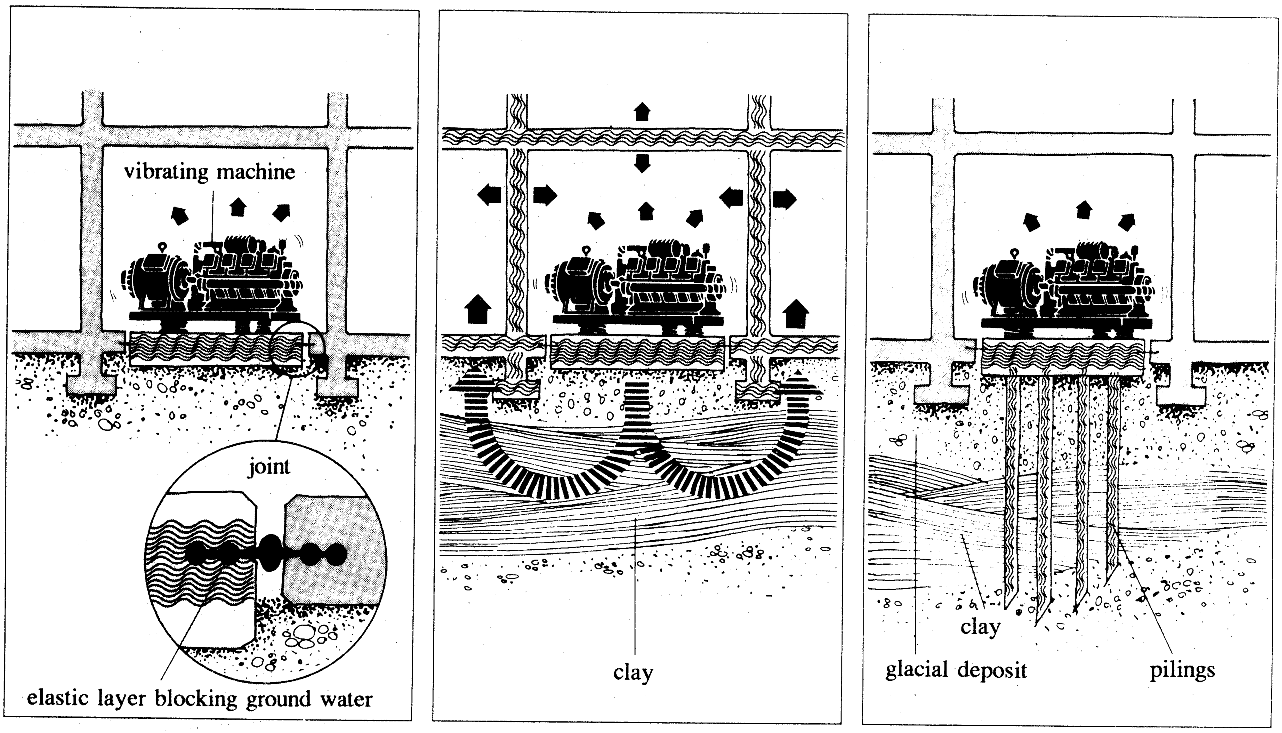
The building is constructed with large concrete plates on a pillar and beam system. The concrete plates which are expected to carry heavy machines are strongly reinforced. If heavy machines are added later, the normal concrete plate is removed and replaced by a thicker one.



A SEPARATE FOUNDATION PROVIDES THE BEST SOLID-BORNE SOUND BARRIER

A good way to isolate very heavy machines which produce low frequency vibration is to install them on thick concrete pads which rest directly on the ground. Even more effective protection is achieved if the concrete pad is separated from the remainder of the building by means of a joint. If the ground has a clay layer, it may be necessary to place pilings beneath the plate.

Principle



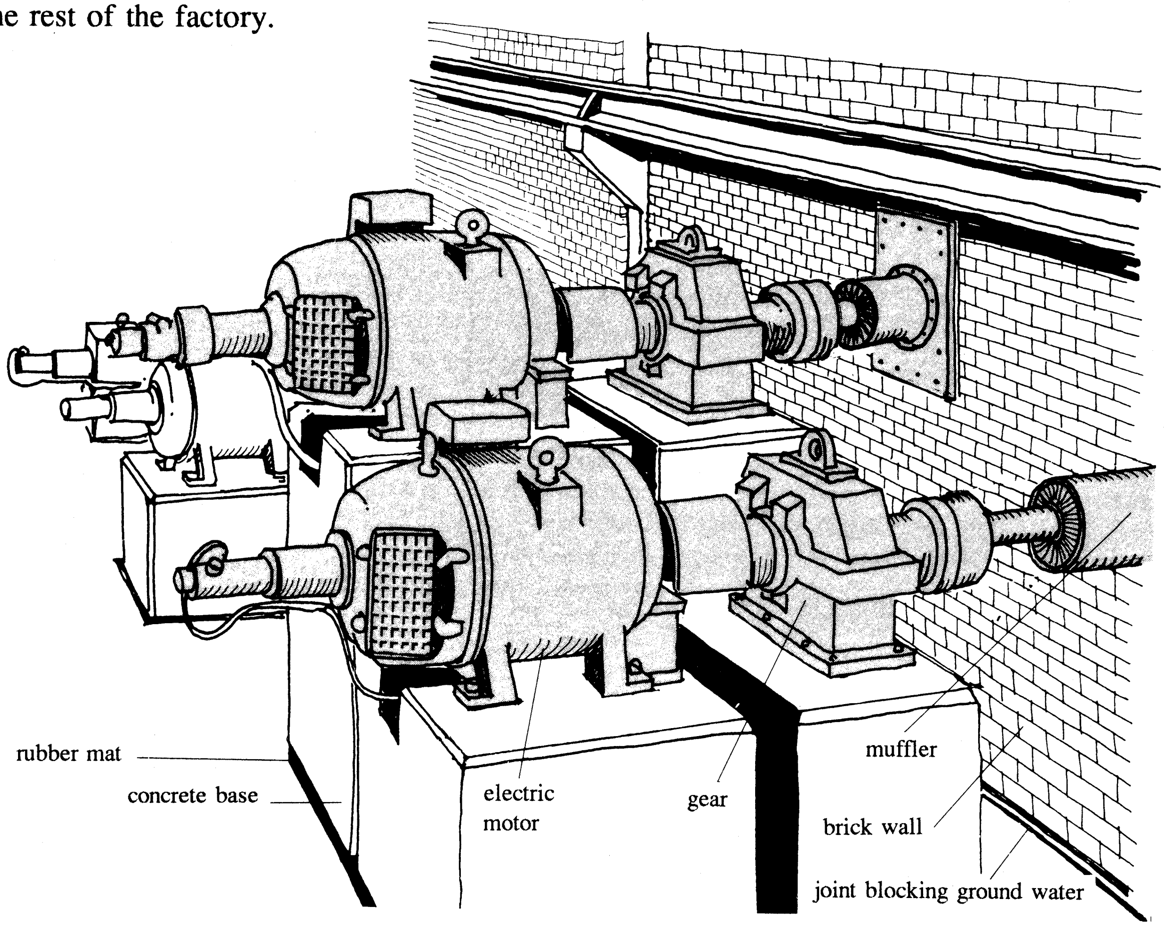
Application to very heavy machines

Example

Drive motors with gearboxes connected to a paper–making machine cause both loud air noise and vibrations in the machines. They require only occasional maintenance which can gererally be performed with the machines turned off. Therefore, the machines can be permitted to make large amounts of noise if the noise is preveinted from entering the rest of the factory.

Control Measure

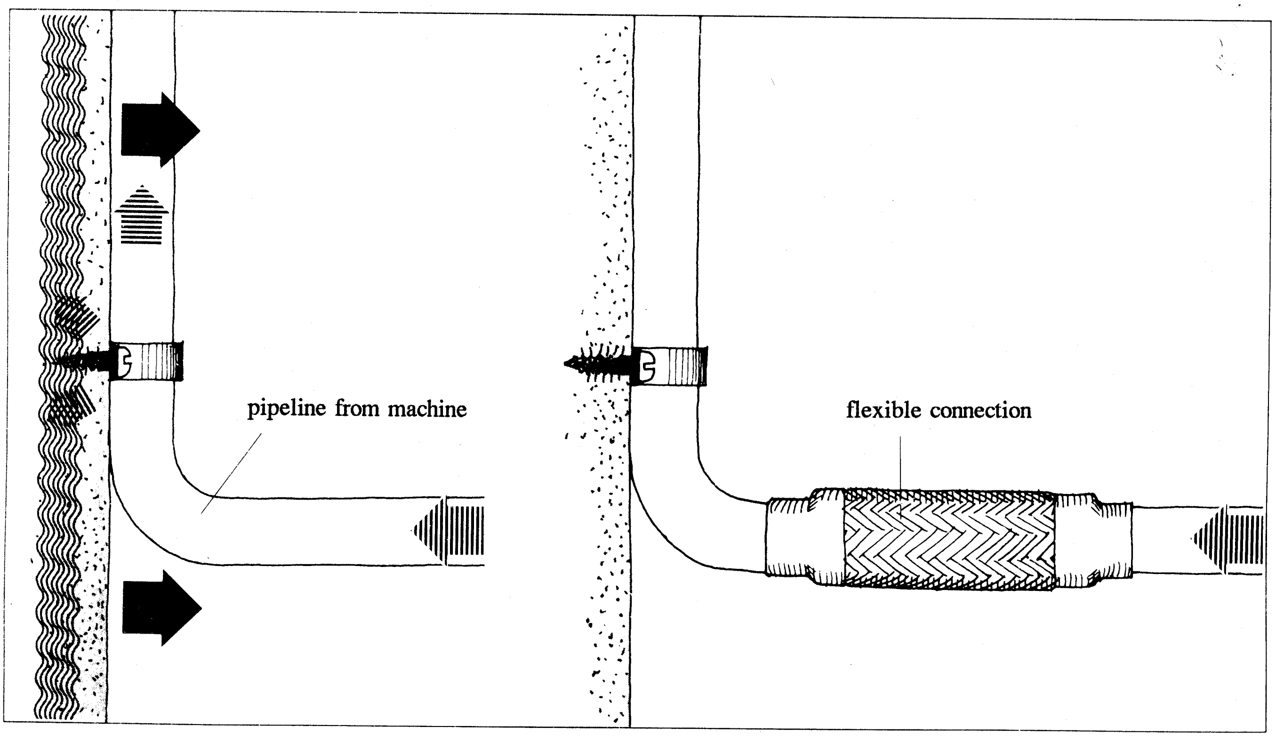
The engine room has its own thick floor slab which is in good contact with the solid ground. The large concrete base blocks are vibration isolated with corrugated rubber mats. Airborne sound is prevented from entering other factory rooms by means of a brick wall. Holes in the wall for axles to pass through are sealed with mufflers.



SOUND THROUGH CONNECTIONS MUST BE BLOCKED

Vibration isolation of a machine may be ineffective if sound is transferred through connections for oil, electricity, water, etc. These connections must be made very flexible.

Principle



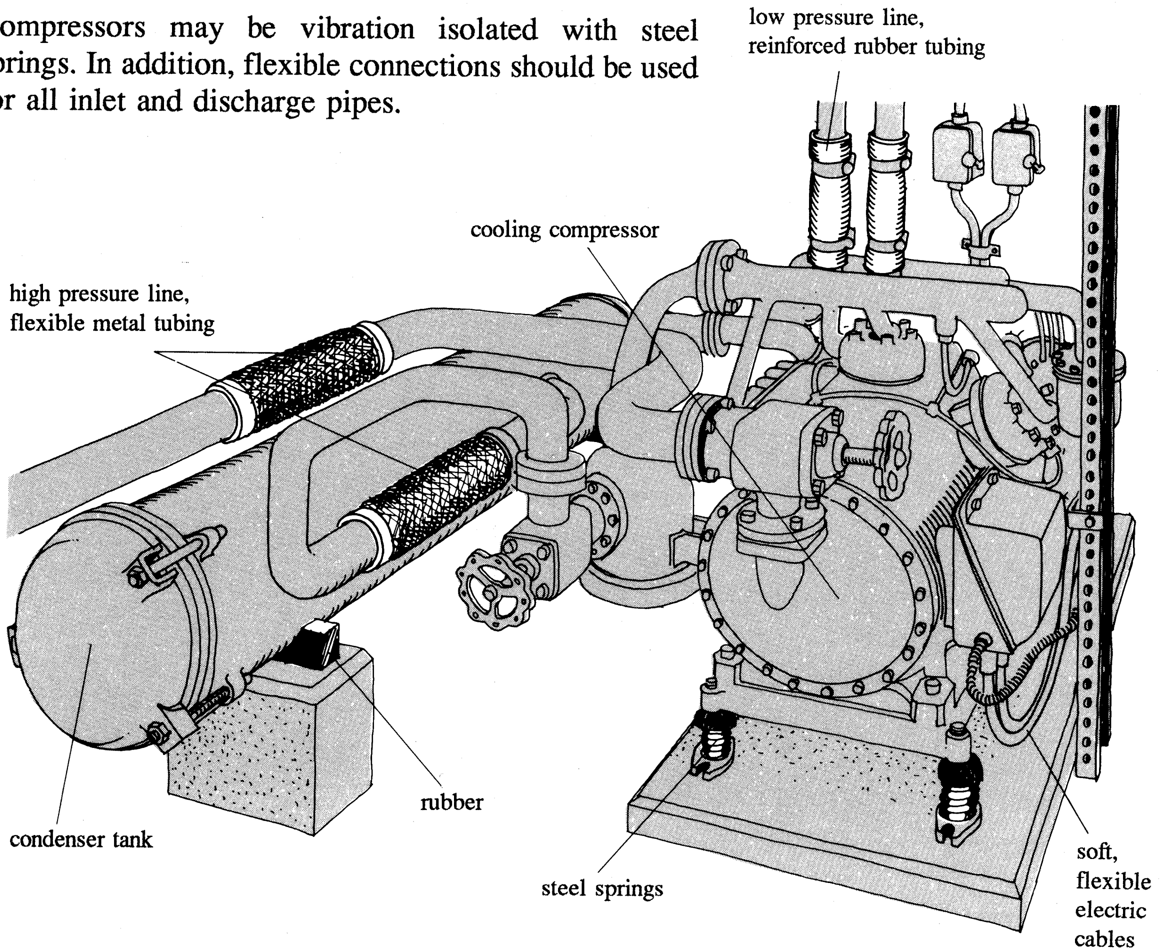
Application to machines with connections for utilities.

Example

Cooling systems may be major sources of noise as a result of intense pressure shocks in the liquid from compressors. Great care must be given to vibration isolation.

Control Measure

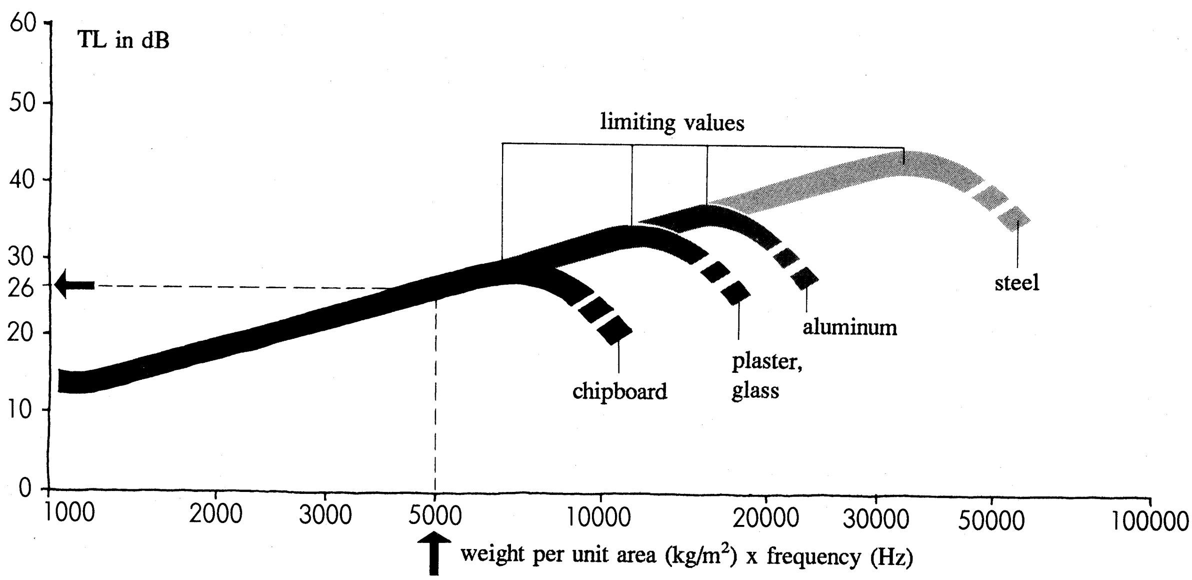
Compressors may be vibration isolated with steel springs. In addition, flexible connections should be used for all inlet and discharge pipes.



THE TL OF A SINGLE WALL IS ESTIMATED FROM ITS SURFACE WEIGHT

Transmission loss (TL) is a measure of a wall's ability to reduce a sound level. At low frequencies and small wall thicknesses, the surface weight in kg/m^2 determines the difference in level between incident and transmitted sound. If the thickness or the frequency are increased, a limit will be reached which depends on the wall material.

Principle



Example: What TL will be provided by a 15 mm thick chipboard panel at 500 Hz? The panel weighs 10 kg/m^2.
Solution: 10 x 500 = 5000. Thus, the TL will amount to about 26 dB.

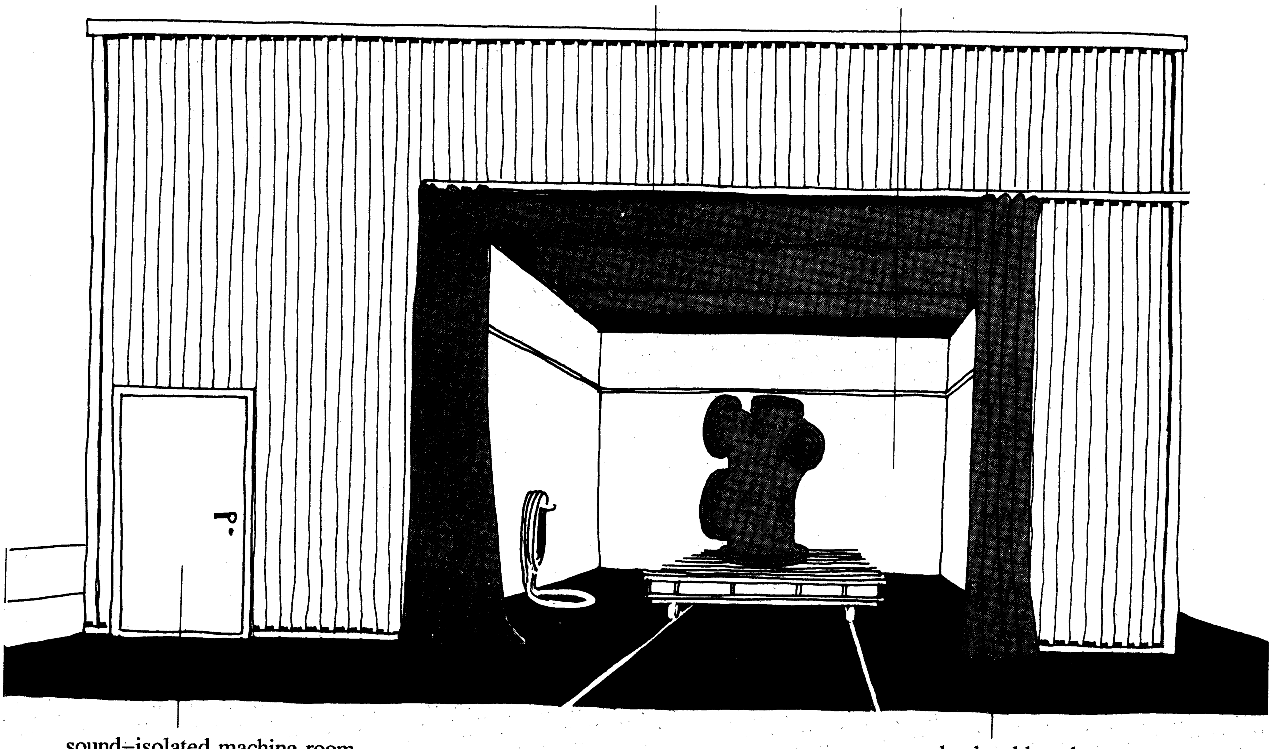
Application with a thin screen.

Example

A sand blast operation creates excessive noise.

Control Measure

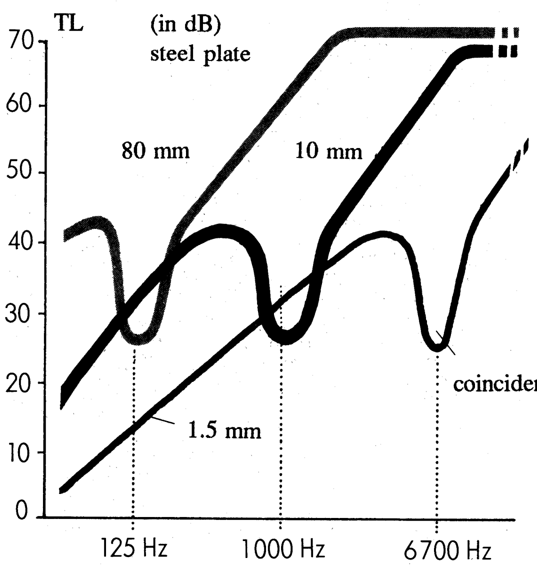
A separate room is constructed for the ventilation fan and other auxilary equipment. The blasting equipment is separated from other work areas with a drapery of lead–rubber fabric, which is heavy but flexible.

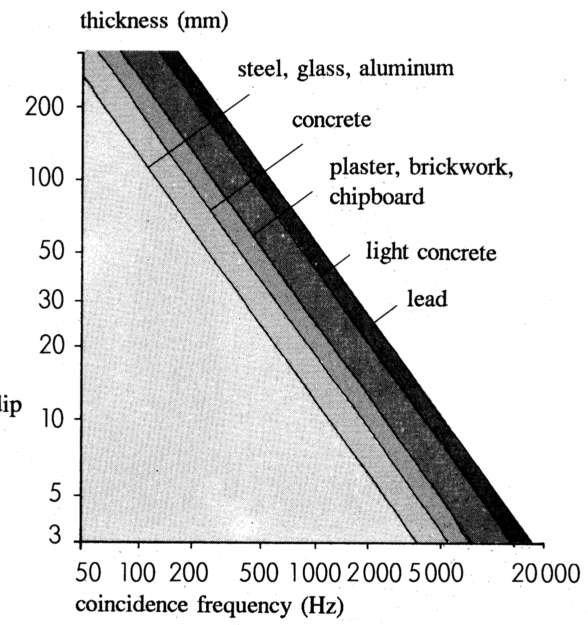


A SINGLE WALL PROVIDES POOR SOUND INSULATION AROUND A CERTAIN FREQUENCY

At frequencies near the *critical* or *coincidence* frequency, the transmission loss of the wall is reduced. At frequencies above the coincidence frequency, the TL will increase again. Only if the wall has high internal damping will the depth of the coincidence dip be reduced. At 1000 Hz, a 1.5 mm thick steel plate gives better insulation than a 10 mm thick plate.

Principle





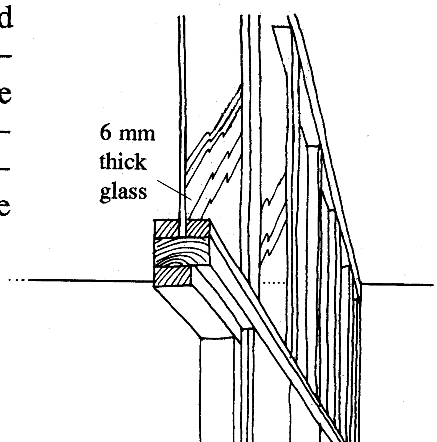
Application with light single walls.

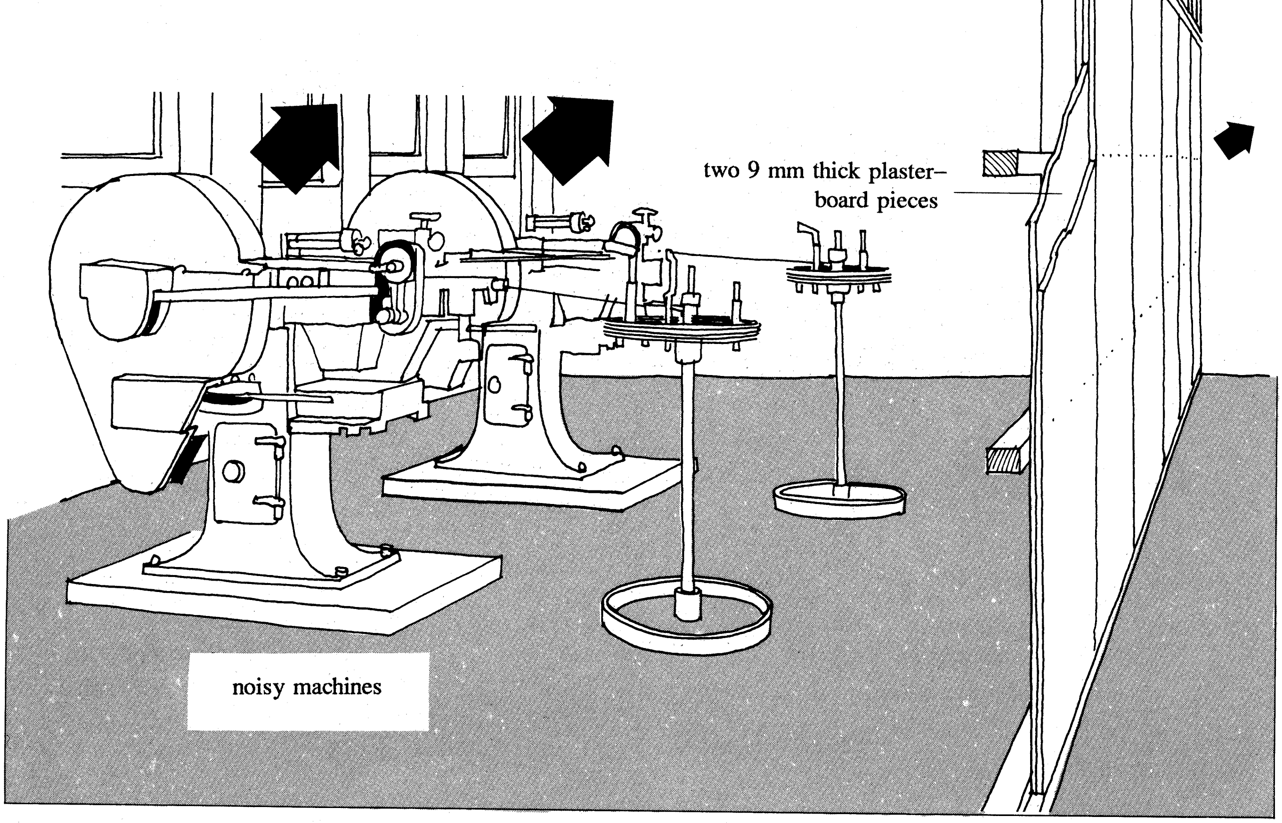
Example

Behind one end wall in a long factory room are a number of machines with an intense noise level peaking at around 1000 Hz. The end of the room is isolated with a wall of 25 mm thick chipboard and 6 mm thick glass. The isolation is ineffective since the chipboard has its coincidence frequency at 1000 Hz while the corresponding frequency for the 6 mm glass is at 2000 Hz.

Control Measure

The chipboard is replaced by two layers of 9 mm plasterboard. Isolation is improved by about 10 dB. The plasterboard weighs about the same as one 25 mm thick chipboard, but it is less than one-fourth as rigid. Its concidence dip is located at 2500 Hz.



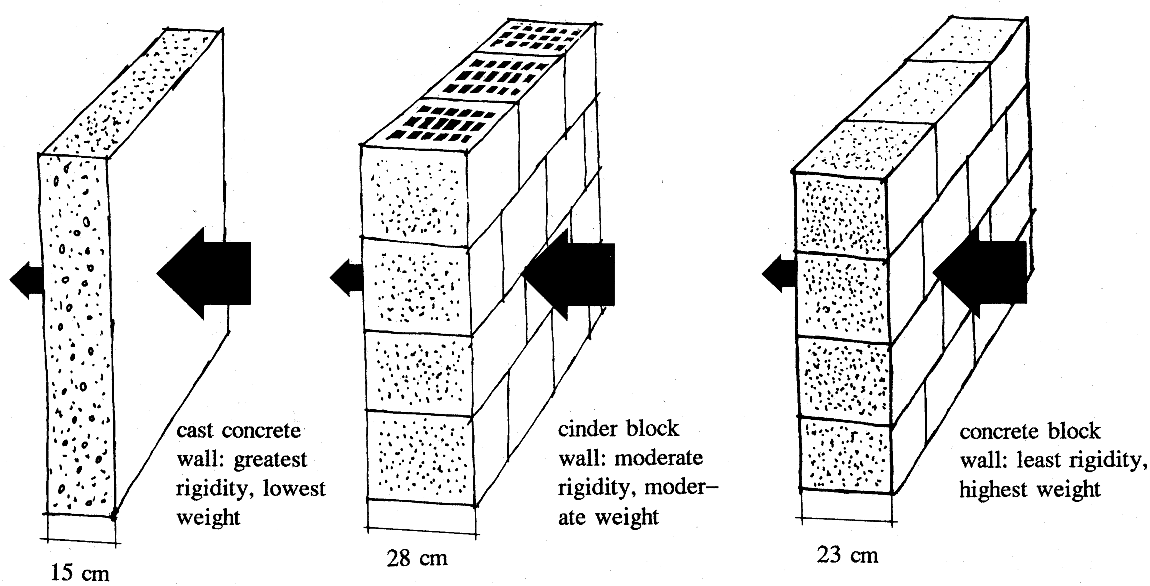


RIGIDITY AND WEIGHT ARE BOTH IMPORTANT IN THICK WALLS

In most single–layer walls, the coincidence frequency is close to 100 Hz for a thickness of about 20 cm. At higher frequencies, both increased weight and increased rigidity produce a greater TL. A cast concrete wall has greater rigidity than a concrete block wall, and therefore provides a greater TL if the two wall weights are the same.

Principle

Walls with same TL. 30 dB at low frequencies, 60 dB at high frequencies, mean TL 55 dB



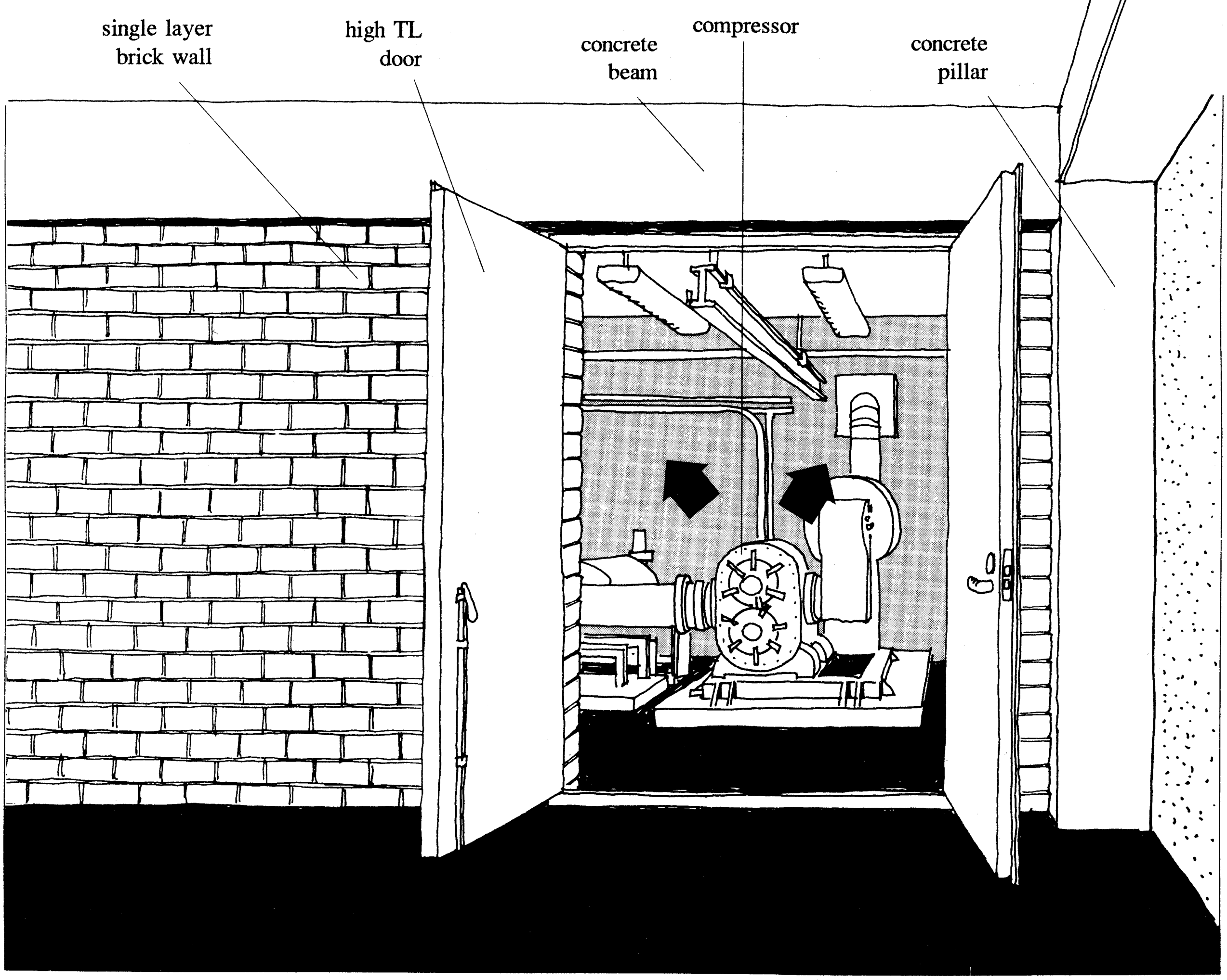
Application with enclosing walls.

Example

Machines in a large open area in an industrial building create a noise hazard.

Control Measure

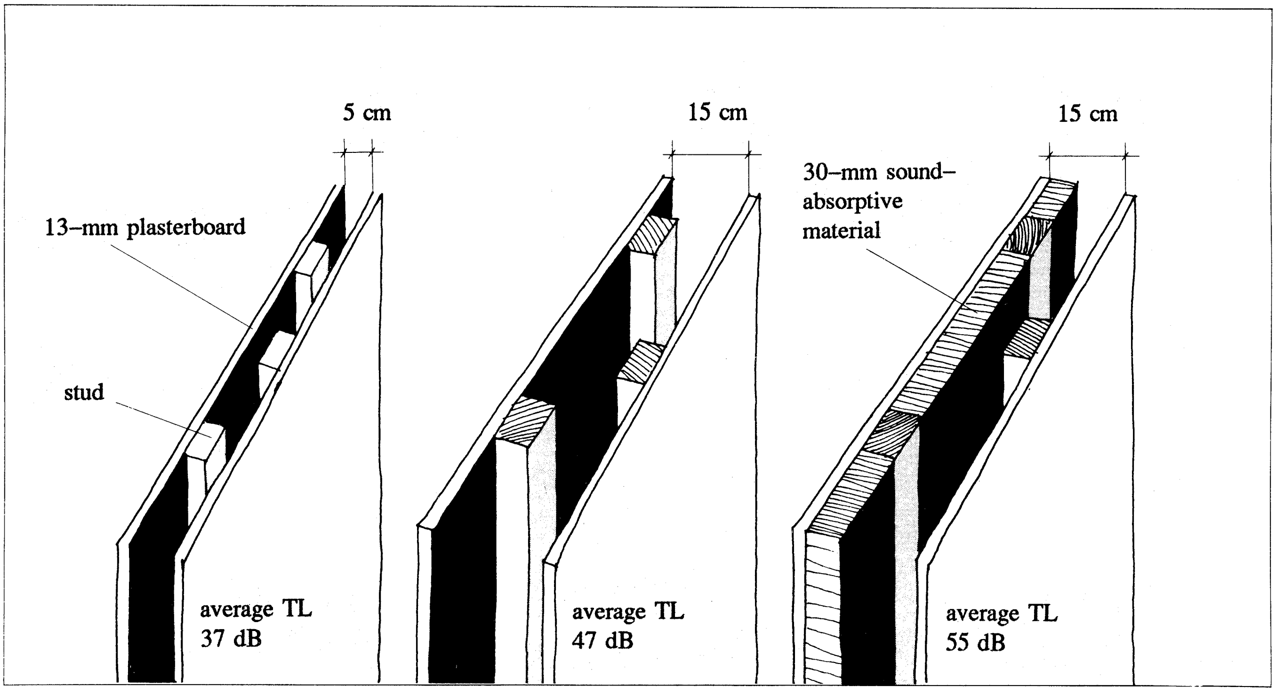
The area containing the machines is surrounded by a brick wall.



LIGHT DOUBLE WALLS PROVIDE GOOD ISOLATION

When two lightweight walls are separated by an air gap, the transmission loss (TL) increases as the spacing of the walls increases — up to about 15 cm. With sound-absorptive material in between, the TL further increases with larger spacings. Double walls may provide the same TL as single walls that are five to ten times as heavy.

Principle



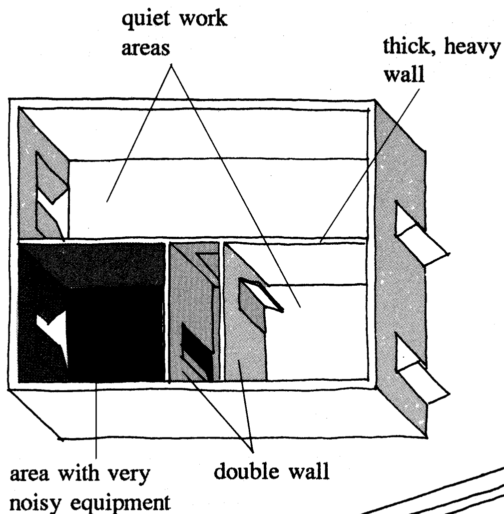
Application in a Work Area with a Few Noisy Machines

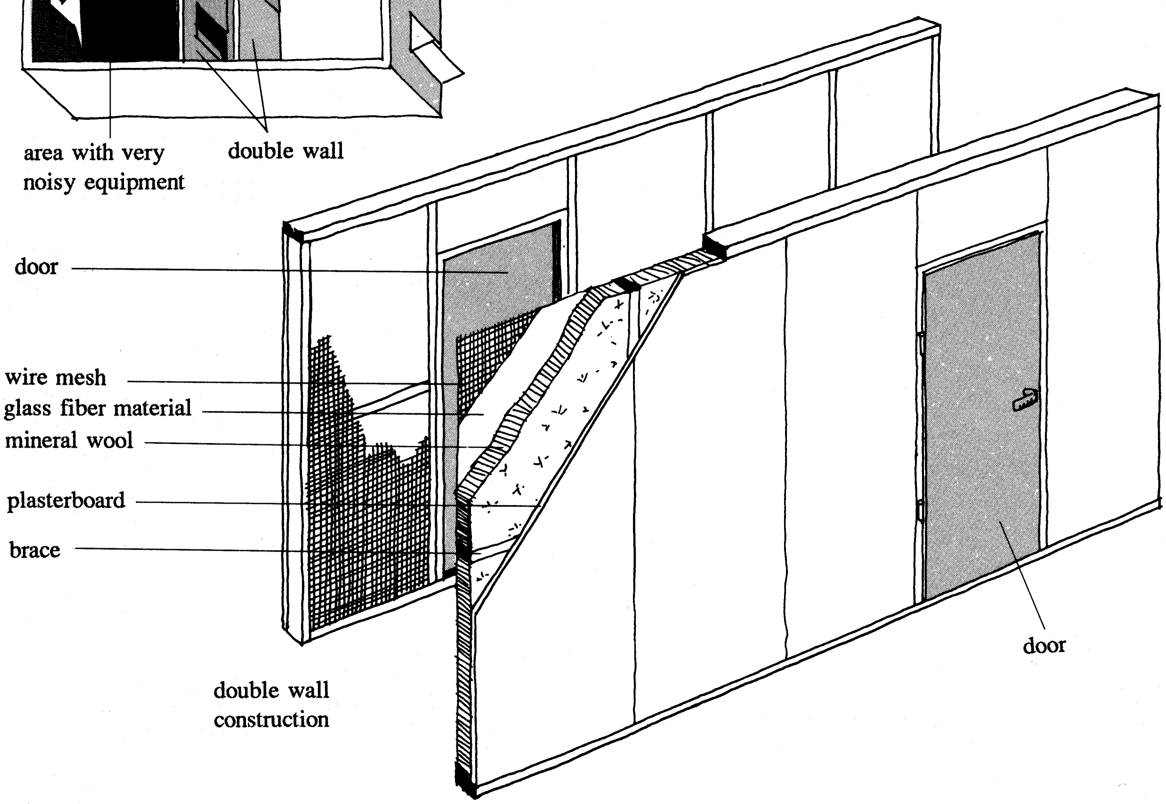
Example

In two adjacent factory spaces separated by a thick heavy wall, a few extremely noisy machines disturb workers in both areas.

Control Measure

The noisy machines are brought together and installed at one end of one room. This room is divided by a lightweight double wall with a TL of 60 dB. The separation of the walls is large enough to create a passageway with doors separating the noisy and quiet areas. The isolation of the areas is at least 35 dB even if one of the doors is left open.

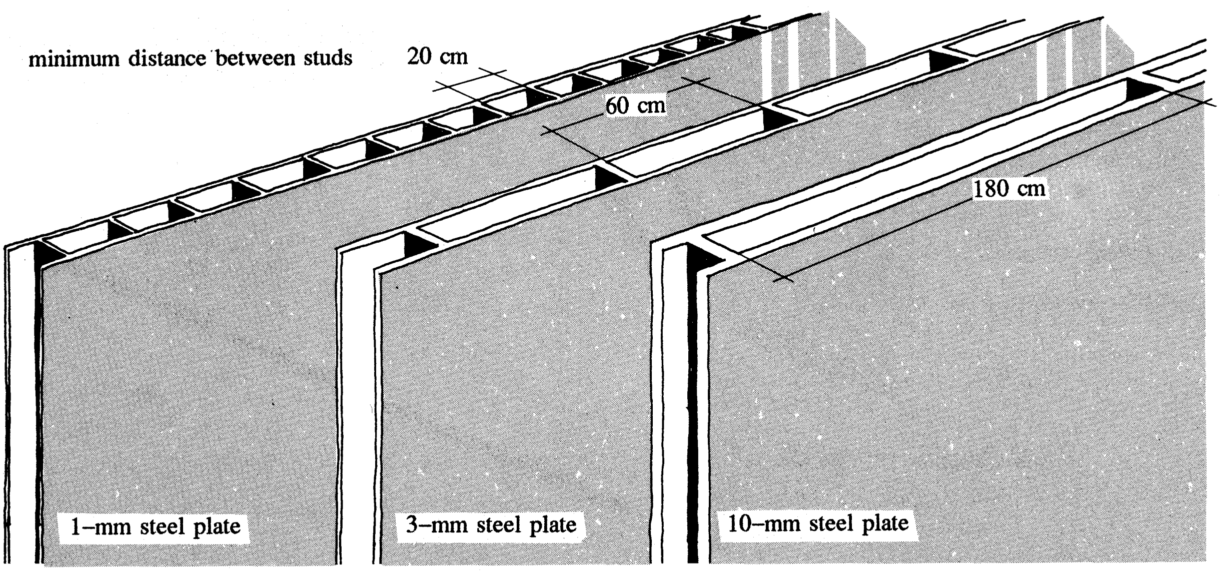




DOUBLE WALLS SHOULD HAVE FEW CONNECTIONS

A double wall provides the best TL if each layer is connected to the heavy walls or if there are open joints on both ends. If the layers are fastened to common studs, the TL is greatly reduced if the studs are close together. The thicker the layers, the farther apart the studs must be in order to avoid substantial reduction of TL.

Principle



Application to a Control Room

Example

The control room for a machine in a paper mill is noisy, and telephone conversations are practically impossible.

Control Measure

A well–insulated room is built with thin panels on common studs. The floor of the room is vibration isolated from the floor of the factory.